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TABLE OF CONTENTS.

LEADING ARTICLES: Page

The McCall Ferry Hydro-Electric Power Plant on the Susquehanna River (illustrated) 267

A Stripping Excavator with a Conveyor to Form the Waste Bank (illustrated). 277

Recent Advances in Artificial Lighting—Arc and Vacuum Tube Electric Lamps (illustrated) 278

The Quebec Bridge (with two-page plate and other illustrations)..... 286

Strength Tests of a Contractor's Dumping Wagon (illustrated)..... 288

EDITORIAL 283

Broad-Minded Methods in Treating Engineering Accidents—The McCall Ferry Power Plant—The Development of Illuminants.

The Quebec Bridge. Our Deficient Knowledge of the Strength of Large Columns (illustrated) 284

LETTERS TO THE EDITOR..... Page 285

The Quebec Bridge Disaster; H. S. Wood, M. Am. Soc. C. E.; Wilhelm Hildenbrand, M. Am. Soc. C. E.; J. W. Schaub, M. Am. Soc. C. E.; W. T. Donnelly, M. Am. Soc. M. E.; F. E. Cardullo.

ENGINEERING NEWS OF THE WEEK..... 289

PERSONALS 289

ENGINEERING SOCIETIES 290

ENGINEERING LITERATURE SUPPLEMENT..... 291

THE McCALL FERRY HYDRO-ELECTRIC POWER PLANT ON THE SUSQUEHANNA RIVER.

The McCall Ferry Power Co. has under construction near the town of McCall Ferry, Pa., on the Susquehanna River, a hydro-electric power plant which is unusual, not only for its size when completed, but for the manner in which the work is being carried out by the introduction of new methods in construction.

The power for the plant will be obtained by damming the Susquehanna at a station on the Port Deposit Branch of the Philadelphia, Baltimore & Washington R. R., called Minqua. The river at this point is approximately 2,700 ft. wide and flows through a valley where the adjacent banks are in the neighborhood of 300 ft. high above the normal surface of the river. This project has been under consideration for many years, and hydrographic surveys have been carried on from time to time during the past decade. The reports made by engineers previous to the time when the present company was formed have looked with favor upon the proposal to develop this valuable water power, but have in a general sense been rather impressive as to the difficulties that would be encountered in construction.

The Susquehanna River is a stream some 400 miles long, draining over 27,400 sq. mi. of the coal country of the Alleghenies. On account of the great mining industry in coal and iron carried on along its banks, its whole length is practically denuded of any forest growth. This, together with the high grades of its drainage area, make it a particularly uncertain stream to control, and one whose sudden rises can not be predicted either in time or amount. The river presents the unusual record of showing a flood condition of 225 volumes of low-water discharge. In the selection of a site for the plant the necessity for a long overfall weir for flood-discharge purposes was kept in mind. Such a weir, 2,500 ft. in length, has been provided, over which the flood waters will attain an approximate depth of 17 ft.

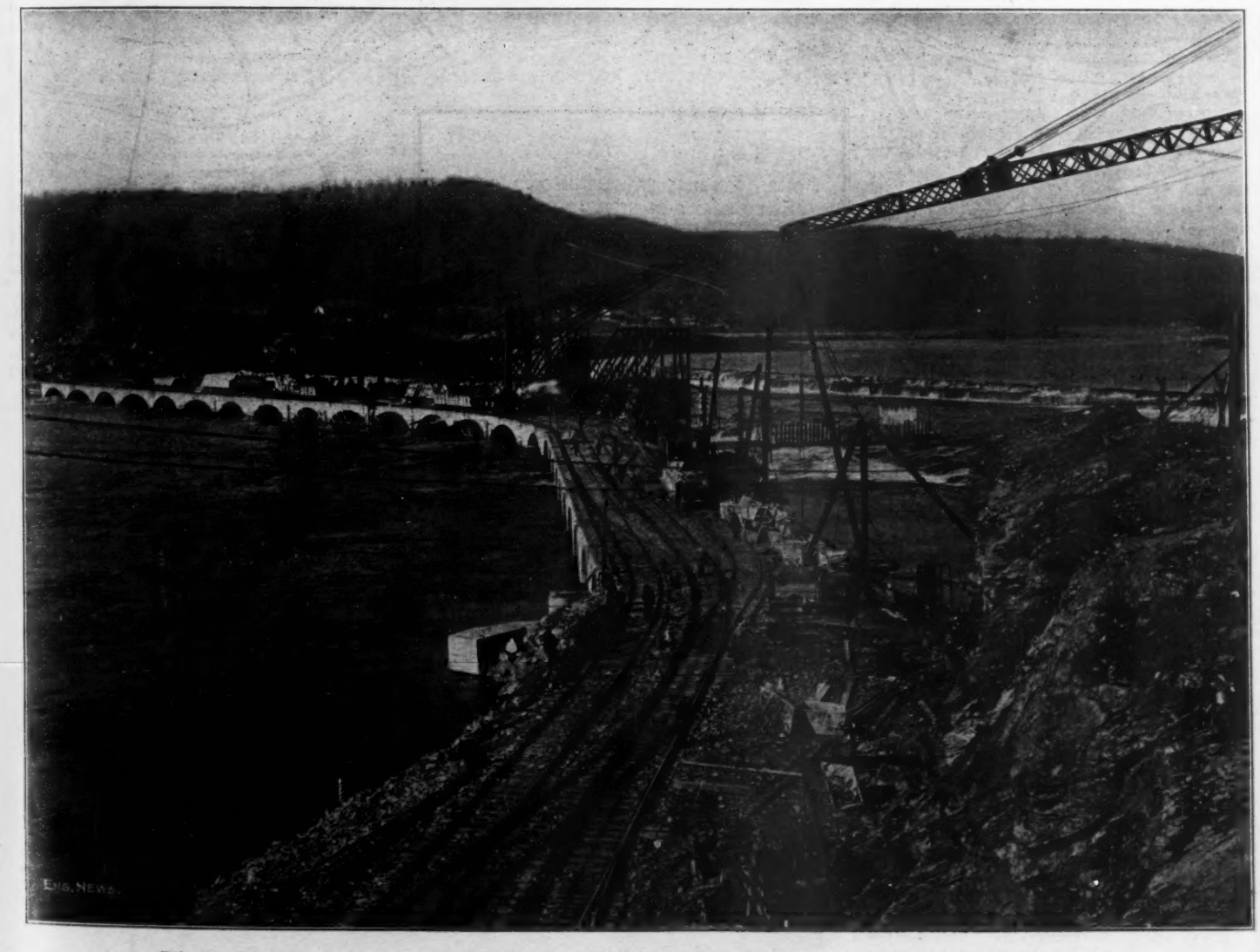

FIG. 1. GENERAL VIEW OF CONSTRUCTION AT McCALL FERRY POWER PLANT ON SUSQUEHANNA RIVER.
(Showing temporary construction bridge, water just topping construction dam upstream and travelers working over steel forms on main dam.)

About two years ago the McCall Ferry Power Co. was incorporated, with a capital of $10,000,000, for the purpose of constructing the hydro-electric plant herein described. The preliminary work of investigation previous to the formation of the McCall Ferry Power Co. was carried on under the direction of the late George S. Morison, assisted by Mr. Boyd Ehle, M. Am. Soc. C. E. The present site of the dam was determined by Mr. Morison.

The question of the construction of this work by contract and set specifications on the one hand and the construction by administration on the other, was exhaustively examined by the officers of the power company previous to the beginning of the work. The difficulties of the undertaking in the way of guaranteed speed of construction, floods, and quality of work required by the company finally determined that the work should be done by administration or day's labor and that the hydraulic work should be put under one management, both as to design of the plant and as to the plans for the execution of the work.

In the major portion of previous investments of this class, the market for power has been less than the capacity of the power plant, thus requiring the investors to wait for the market to grow to a satisfactory dividend basis. At McCall Ferry, however, the reverse is true and in this particular installation it is found that a circle with its center at the power plant and with a radius of 70 miles, will include within its bounds Philadelphia, Baltimore, Wilmington, Harrisburg, York, Lancaster and other centers, wherein by actual canvas it is found that there is now in commission the enormous sum of 750,000 steam HP., to supply which the power company will offer in the vicinity of 100,000 HP. This feature is particularly advantageous to the power company for the reason that it can select its market to the best advantage.

Description of Power Plant.

The engineering department of the company has been from the first instructed by the power company officials to the effect that the finished work should be absolutely first class, the company believing that true economy is only found in making things right in the first place, thereby obviating the abnormally large maintenance and renewal expenses which have been so prominent in many hydro-electric plants hitherto designed.

The general layout of the plant is illustrated in Fig. 2. The water is directed to the power-house by a large concrete spillway dam and before entering the forebay passes through the outer screening works, of which the rock fill directly north of the power-house is the outer portion. The rock-filled ramp and the dam are connected by screening works consisting of a concrete-arch ice-fender and a set of floating booms, as shown on the drawings. The purpose of the arches and booms is to restrain ice and debris coming down the river from entering the forebay and keep such material in the line of travel over the top of the weir. The area for the admission of the water to the forebay is so large that the velocity of the water at the entry will not be over 1½ ft. per sec., thus reducing to a minimum the liability of trash being sucked down under the arches and booms and carried into the forebay. The water, after passing through the power-house, is returned to the main river by the use of a natural tail-race about two-thirds of a mile long. At the lower end of this natural tail-race about 150,000 cu. yds. of rock is being taken out to complete the necessary 53-ft. operating head at low water.

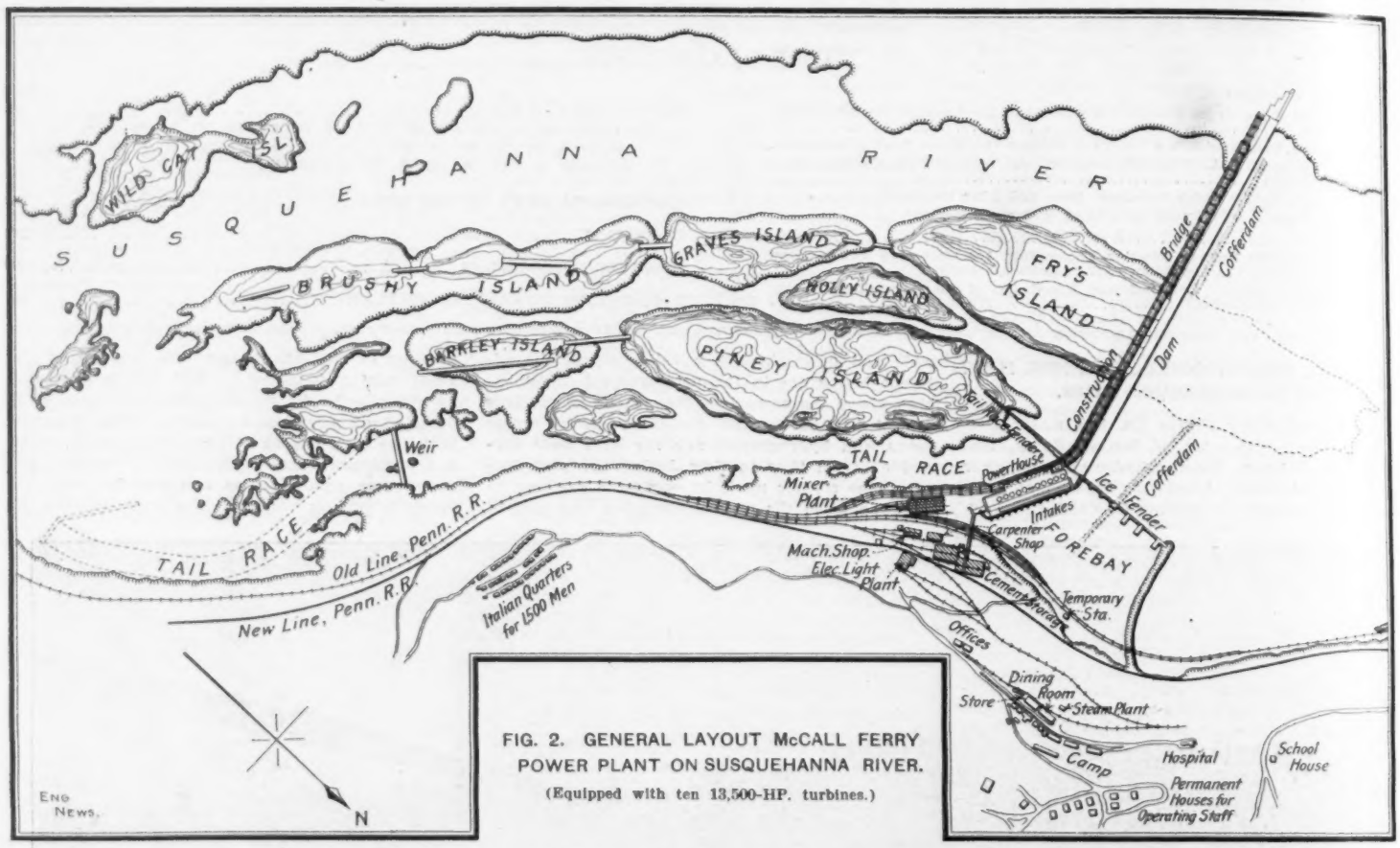

FIG. 2. GENERAL LAYOUT McCALL FERRY POWER PLANT ON SUSQUEHANNA RIVER.
(Equipped with ten 13,500-HP. turbines.)

MAIN SPILLWAY DAM.—Fig. 6 shows the section of the main spillway dam, together with the stress-sheet. It is built, throughout of non-reinforced mass concrete, with approximately 18% of pudding stone distributed throughout the section, and for its whole length is founded upon a solid rock bottom excavated out of a micaceous

FIG. 3. ALTERNATE SECTIONS OF COMPLETED DAM AT HIGH WATER.
(Crib dam completely submerged.)

schist, very close-grained and sound and entirely suitable for foundation purposes. The strength of this rock foundation is not reached by the maximum pressure of six tons shown on the stress-sheet as acting under an overtopping flow of 17.5 ft. In the middle of the river, the dam crosses an island and shoal where the rock bottom is at a much higher elevation than in the bed of the river. At this point, the lower down-stream edge of the dam is formed of the same curve as in the river bed, but raised some feet higher. This causes a warp in the surface where the two join, but is designed so that the same steel-frame forms could be used on all the dam, as afterwards described.

POWER-HOUSE. — Cross sections through the power-house and one of the turbine units are shown by Figs. 4 and 18. The power-house is constructed of concrete, with steel roof trusses, and is built upon solid rock foundations of the same quality and treated in the same manner as described for the main dam. The power units consist of ten pairs of Francis turbines, mounted on vertical shafts. Each of these units, operating under normal conditions at 8-10 gate opening, 53-ft. head and 94 r. p. m., is designed to produce 13,500 mechanical HP. The minimum head will be 43 ft. in times of high water and as the head is reduced from 53 ft. the gate openings will be increased to full open to maintain the normal speed, and at 43 ft. head the output per unit will be 12,000 mechanical HP. These turbine settings complete weigh in the neighborhood of 700,000 lbs. each and the runners are approximately 10 ft. in diameter. The units are probably the most ambitious examples of turbine construction hitherto attempted. They are being manufactured by the I. P. Morris Co., of Philadelphia. The design of the turbine settings, the leads for the water and the massive foundations provided for reaction pressures and for the destruction of vibration, are elements that have been given a great amount of study, and it is believed that the results will justify the expenditures that have been provided for this part of the work.

The rotor weighs approximately 194,000 lbs. It is carried on an oil-thrust bearing in which the disks are separated by a film of oil fed to the bearing under a pressure of 250 lbs. per sq. in. Each turbine is supplied with an independent oil-pressure system in which the oil pressure is provided by an independent 50-HP. turbine actuating the oil-pressure pump in advance of the starting of the wheels proper and continuing this work as the wheels are in operation. The same set of pressure pumps can also be operated either by electricity or by a direct drive from the main shaft after the wheels are in operation. Each turbine is direct-coupled to a 7,500-KW., three-phase, 11,000-volt, 25-cycle General Electric generator. The field current is furnished by two 1,000-HP. independent exciter sets generating at 250 volts and 240 r. p. m., all direct-connected, as shown, for the main unit.

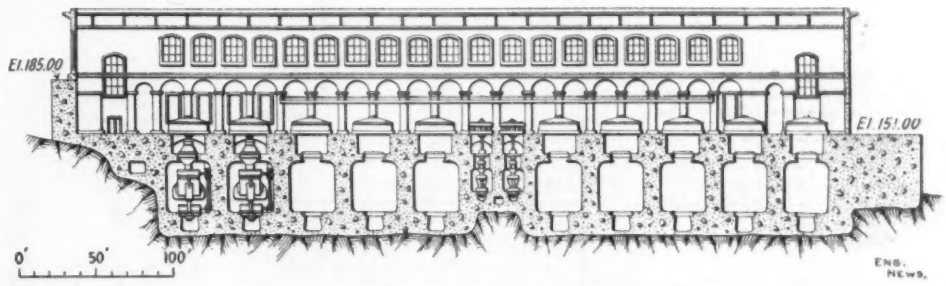

FIG. 4. SECTION THROUGH POWER HOUSE.

Previous practice in similar cases of wheel settings to the one here under discussion, has rather uniformly called for metal conduits to lead the water to the wheels, metal casings surrounding and constituting the wheel chamber, and metal for draft tubes. As will be observed in the cross-section, no metal is used for any of the elements above described. The entire structure is built of non-reinforced concrete and the various complicated forms necessary for the maintenance of uniform velocities and the destruction of eddy currents have been secured by the use of intricate wooden-form work overcovered by steamed basswood. The forms for this class of work have been removed in a large portion of the work and the smoothness of the concrete and general appearance of the same seems to assure the wisdom of this method of handling water to and from the wheels. Certainly a large sum of money has been saved in first cost as well as a considerable saving in maintenance in future operation.

FIG. 5. ALTERNATE DAM SECTIONS, SHOWING EXPANSION JOINTS AND BUTT BLOCKS FOR STEEL FORMS.

TAIL-RACE.—The photograph reproduced in Fig. 11 shows a view of the tail-race looking up-stream toward the site of the power-house. This tail-race is a very peculiar natural formation, the existence of which was one of the factors in the selection of this particular site for the plant.

As has been stated, the river is about 2,700 ft. wide and varies in depth from an average of 8 ft. in the main river to a depth of 25 ft. in the tail-race. This natural tail-race required but very little excavation to produce the required discharge capacity. For the purpose of keeping flood waters out of the tail-race and keeping it clean from flood-water deposits, the main dam will be connected to the chain of islands constituting one bank of the tail-race by what is called on Fig. 2 "Tail-Race Fender." This wall will have a height sufficient to keep flood waters out of the tail-race and the gap in the islands below this wall will be filled in, as shown on Fig. 2, for the same purpose. The lower end of the tail-race, as already noted, terminates at approximately Cully's Falls, about two-thirds of a mile below the plant.

At this point some 150,000 cu. yds. of rock excavation have been taken out for the purpose of securing the additional head that exists in the rapids at Cully's. This excavation work, owing to its distance from the main work, was originally planned to be done by contract, and a contract was entered into for the removal of this excavation. The contractor, however, failed to finish the work in contract time and it was taken over by the company to be completed by administration.

Construction Work.

On account of the extraordinary conditions of flow, it was believed unwise to use previous methods of construction. Hitherto it has been the plan to unwater a portion of the river, construct the foundation thereon and build through the dam or power-house a set of sluice gates to handle the water of the river while the second half of the river bed was being covered. An examination of the flow of the stream for a period of 14 years seemed to show that to progress the work so that it might be completed in approximately two years, it would be wise to provide during the construction period for the safe discharge of at least 50,000 cu. ft. per sec., or else submit to very long delays waiting for periods when the river was at a materially less flow. This has been fully proven by the experience gained during construction. To use sluice-gates with a discharging capacity of 50,000 cu. ft. per sec. under ordinary conditions would have entailed the expense of the construction of approximately 50 gates with a cross-section of 60 sq. ft. each. These gates in themselves would have been a large item of expense and the uncertainties incident to their use, owing to their clogging up with ice during the winter season and with debris from the river during the balance of the season, would have resulted in certain extra expense and vexatious delay, if indeed the sluice-gates would have been feasible for the work in question. The building of the dam as shown in the views, leaving alternate 40 ft. sections low, has provided for the ability to discharge 50,000 sec. ft. through the openings thus left for the purpose. The areas for the discharge of water under the construction bridge were likewise sufficient for the 50,000 sec. ft., thus permitting the work to proceed during the times when that amount of water or less was being discharged and allowing the work that was above the water surface to be continually progressed.

The problem thus presenting itself was to find a method of construction whereby a dam 50 ft. high and 2,700 ft. long could be built across an

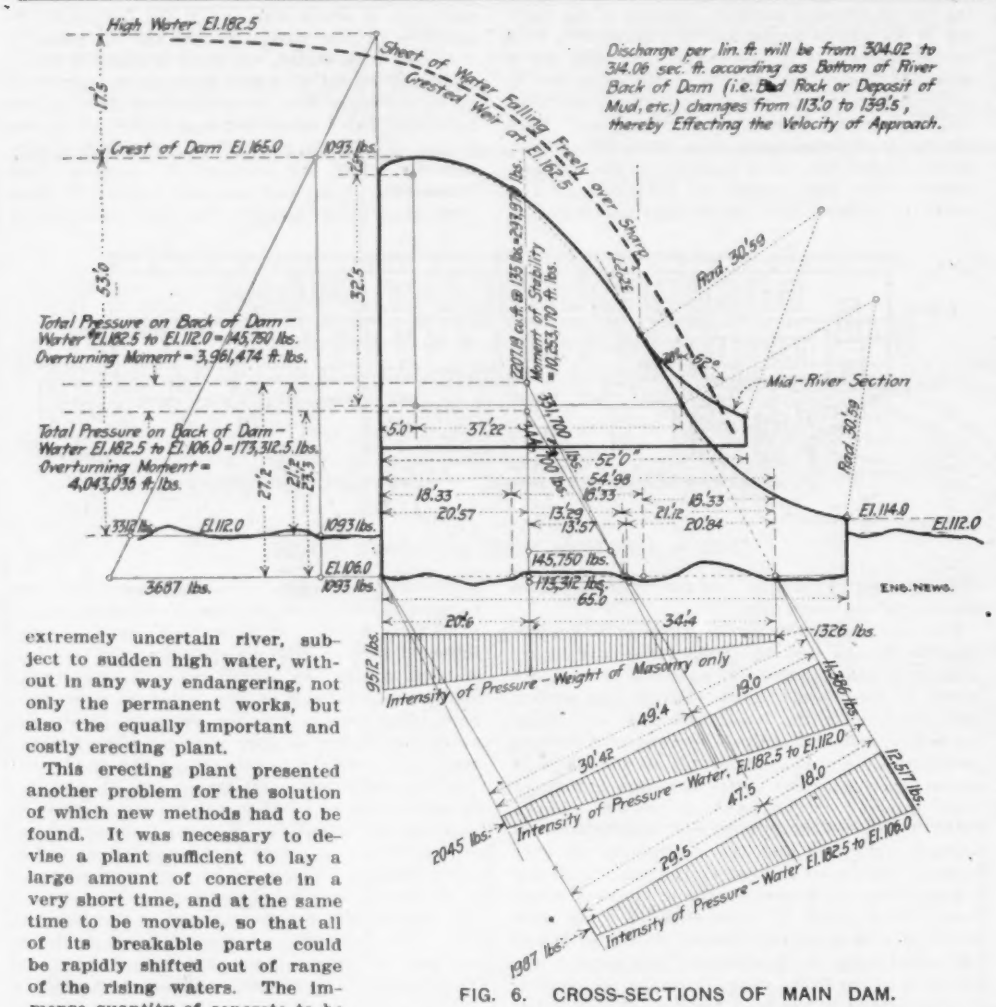

FIG. 6. CROSS-SECTIONS OF MAIN DAM.

extremely uncertain river, subject to sudden high water, without in any way endangering, not only the permanent works, but also the equally important and costly erecting plant.

This erecting plant presented another problem for the solution of which new methods had to be found. It was necessary to devise a plant sufficient to lay a large amount of concrete in a very short time, and at the same time to be movable, so that all of its breakable parts could be rapidly shifted out of range of the rising waters. The immense quantity of concrete to be laid, 350,000 cu. yds., required size and the possible 50,000 sec.-ft. of water inside of 24 hours required flexibility.

Luckily the physical features of the site lent themselves to a treatment of the problem which, while being unique in its many features, has proved eminently successful. The river at this point (Fig. 2) is divided into two branches by Fry's Island, which rises to an elevation above the main footings of the dam. Briefly, the scheme adopted was as follows: A temporary crib dam was built from the east or Lancaster shore of the river to the Island which, with other cribs to prevent back water, threw all the flow of the river through the west or York channel between the Island and the west bank. Across the dry Lancaster channel, the dam was built in alternate 40-ft. sections, as shown in many of the illustrations. The openings were built up high enough to give foundations for filling them afterward. At the same time, the power-house was carried up to an elevation sufficient to finish all the intake pipes and allow a free flow through them out into the tail-race. Simultaneously with the last part of the Lancaster channel work a cofferdam was thrown across the York channel in alternate sections so that, at the finish of this first part of the Lancaster channel work, the whole flow of the river was passing through the open sections, which equalled half of the York channel.

At this time, the Lancaster channel crib was opened with dynamite and the flow allowed to pass down the river through the alternate openings in the finished dam. The York channel dam is now being built in alternate sections in the same manner as the other half. It will not be possible to use any part of the power-house intakes to handle water for construction purposes until the alternate dam openings are filled to an elevation approximately 25 ft. higher than the elevation now existing.

After the work of placing the foundations in the York channel is completed and the openings are provided in this structure the same as shown now in the Lancaster channel, the river will be rediverted to the York channel and the excavation still to be done in the tail-race will be progressed to completion. It is expected that this work will be finished in the early spring of 1908. Then the alternate sections in the two channels will be completed five feet in elevation at a time, shifting the work from one channel to the other and handling the water by means of the stop-logs described below.

STOP-LOGS.—These hollow stop-logs (Fig. 10) will consist of steel skeleton frames, 44 ft. wide and 16 ft. high, one stop-log being provided for each opening. The stop-logs when not in use will be suspended from the top of the dam. As it is desired to cause all of the water to flow either through the York channel or through the Lancaster channel of the stream whenever either channel is to be dried, the stop-logs will be dropped into their closure position and as the logs are skeleton in design they will sink to their actual position of their own weight.

After the skeleton framework is anchored in position, a heavy canvas curtain will be unrolled over the skeleton work and the water pressure will seat the canvas against the framework of the log. Having in mind that the faces of masonry against which the stop-logs will take bearing will of themselves not be practically true and therefore that the log cannot make a perfect seat, the actual connection between the masonry and the seat of the log will consist of a 4-in. heavy collapsible cotton hose which will extend continuously down the two sides of the log and across the bottom thereof. When it is desired to shut off the water for the depositing of masonry, the cotton hose will be inflated with compressed air. The bottom of the log will always be 2 ft. below the bed of the masonry in the opening which is to receive concrete. This 2-ft. width below the bed of the masonry is to act as a trough to gather the minor leakages through the pipe gasket and canvas, and this leakage will be pumped out and kept below the new masonry bed by a small pump on each log.

The design of the log is such that it will of itself furnish the form for the new masonry that is to be put in place. It is planned to place only 5 ft. of concrete at a time on each set of openings in each channel.

When 5 ft. of new concrete has been put in place and properly set the stop-logs for this channel will be raised to the top of the dam and the operation repeated for the openings in the opposite side of the river. In other words, the use of these stop-logs, which may be called portable cofferdams, while very inexpensive in themselves (costing less than $20,000 for the entire outfit) has obviated the necessity of the construction for this particular work of a cofferdam 2,500 ft.

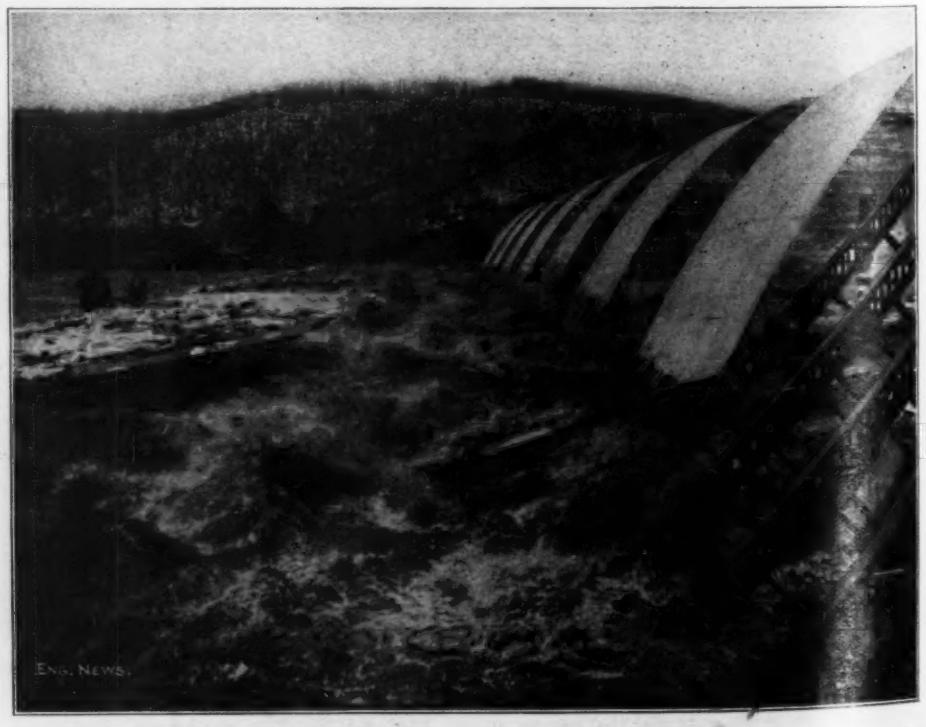

FIG. 7. HEAVY FLOOD OF MARCH 15, 1907, PASSING BETWEEN ALTERNATE SECTIONS.
(Construction bridge was completely submerged later in the day. Compare with other photographs showing normal stages of water.)

long and 40 ft. high, a structure that in this locality would cost in the neighborhood of $500,000.

ERECTING PLANT.

The rapidity and efficiency with which so large a work can be carried on depends largely upon the erecting plant and its design, and in this particular instance the aim has been to provide for progress with a minimum of labor. The design of the construction works for this development was greatly aided by the natural topography of the surrounding country.

In the first place the line of the Pennsylvania Railroad runs parallel with the river from its mouth to the site of the dam and beyond, thus offering ample means of communication with the outside source of supply and necessitating a minimum amount of local track work. The layout of the plant connected with the main line of the railroad is shown in Fig. 2. The amount of construction railway, however, necessary at the plant at McCall's Ferry, together with that necessary at the quarry at Conowingo, Md., amounts in all to approximately 14 miles of single-track railway. Taken at a point about ¼-mile below the dam, construction tracks were built branching from the main line of the Pennsylvania Railroad and running at different levels to all parts of the construction camp. On the drawings the tracks farthest from the river are on the highest level to reach the commissary buildings and the air-compressor plant. In order to build the dam with its crest at the present elevation of 165, it was necessary to make arrangements with the Pennsylvania Railroad for the reconstruction of some 14½ miles of its railroad, 9½ miles of which new construction was above the dam and 5 miles below the dam. All construction tracks of the power company are standard gage and all materials in the way of sand and broken stone for concrete arrive in hopper-bottom cars, which are dumped directly into open bins in the concrete mill.

Power for practically the whole plant, embracing altogether some 60 different units of engines of different types, is supplied by compressed air from a central power plant. This central power plant consists of two 400-HP., 2-stage Sullivan compressors, connected with Corliss compound condensing engines supplied by steam from four 200-HP. boilers. This air is used at an average working pressure of about 90 lbs., and is carried to all parts of the work, the furthermost present point of use being approximately 4,000 ft., from the central station. In addition to the central power plant the construction outfit is equipped with a machine shop, in which the usual provision is made of lathes, jumpers, drill-presses, power-hammer, blacksmith forges, bolt-cutters, etc.

The construction camp is lighted by its own electric light plant, which consists of one 90-KW. alternating-current machine. The usual provision has also been made for a carpenter shop, storehouse for 100,000 bbls. of cement and a general storehouse for small supplies.

CONCRETE-MIXING PLANT.—One of the largest factors in the rapid construction of this work is the mixing plant. This is probably the largest plant for the mixing of concrete ever constructed in this country. It has a capacity of 2,000 cu. yds. in a ten-hour day of well-mixed concrete and a storage capacity of 14,000 cu. yds. of concrete material. The location of the mixing plant can be seen from the layout of the works, Fig. 2. Detailed design is given in Fig. 14. The yard tracks at Elev. 173, switch, as mentioned above, from the main line of the railroad to four lines of track which run into the mixer house. These rails are supported by the walls of the bins, leaving an open space beneath for the free dumping of material into the bins marked "B" and "C." Bin "B" is for sand and is provided with a sloping chute. Bin "C" is for stone. The bins are emptied by trap doors in the floor. Cement is brought in on the track at the extreme left, at Elev. 166. It is stored in Bin "A," and dumped to the mixing car direct through the hoppers shown. All five of these yard tracks are connected directly to the main line and all trains carrying cement from the cement mill and the storehouse, sand from the sand deposit and stone from the quarry are switched over the bins upon arrival and dumped. Frequently as many as 75 50-ton capacity carloads of material arrive in a day.

Lengthwise the house is divided into eight compartments, each one contributing to a 1-yd. Smith

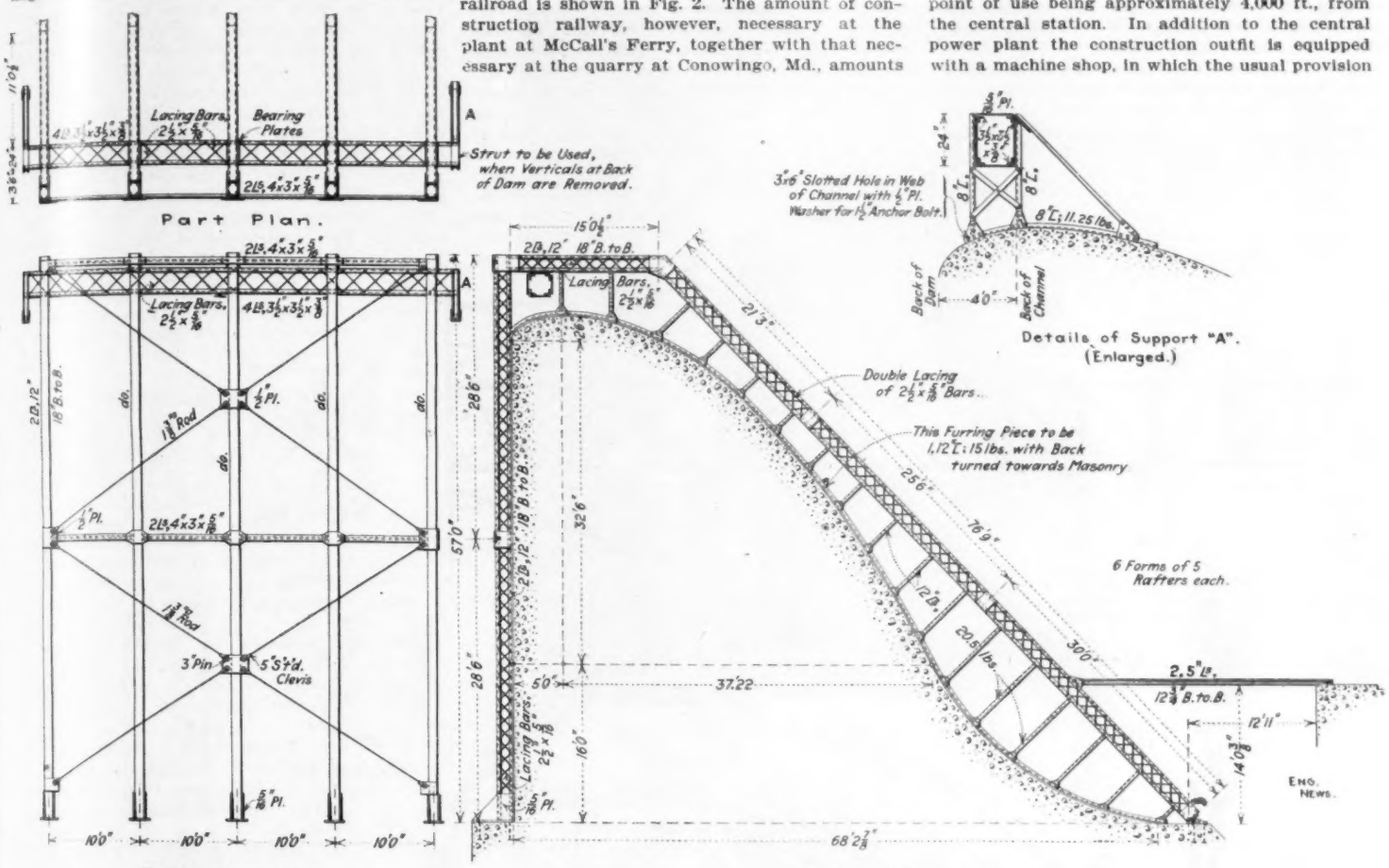
Part Plan.
Lacing Bars.
Bearing Plates.
Strut to be Used, when Verticals at Back of Dam are Removed.
End Elevation.
Side Elevation.
Details of Support "A". (Enlarged.)
3"x6" Slotted Hole in Web of Channel with ½" Pl. Washer for 1½" Anchor Bolt.
Back of Dam
Back of Channel
Double Lacing of 2½"x⅝" Bars.
This Furring Piece to be 1,12"L; 15 lbs. with Back turned towards Masonry
6 Forms of 5 Rafters each.
2,5"Lg.
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FIG. 8. STEEL FORMS FOR DAM SECTIONS.

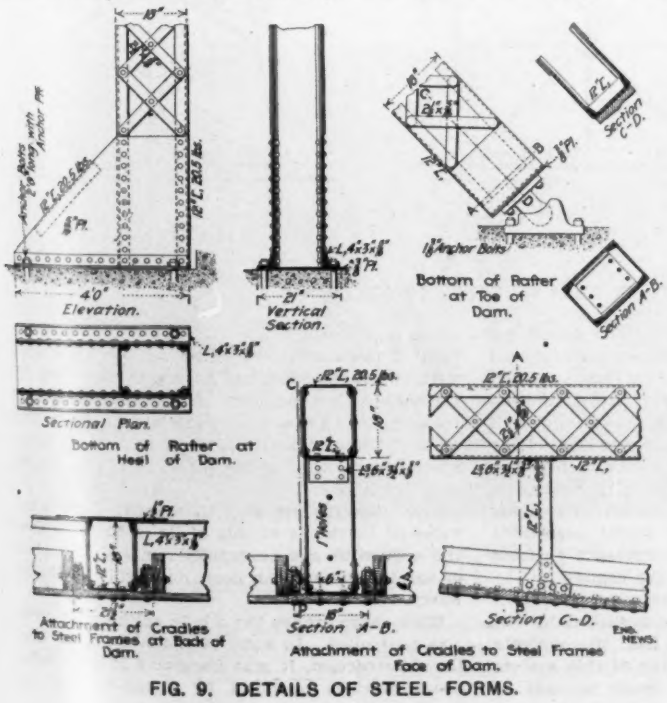
Elevation.
Vertical Section.
Anchor Bolts
Bottom of Rafter at Toe of Dam.
Section A-B.
Section C-D.
Sectional Plan.
Bottom of Rafter at Heel of Dam.
Attachment of Cradles to Steel Frames at Back of Dam.
Attachment of Cradles to Steel Frames Face of Dam.
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FIG. 9. DETAILS OF STEEL FORMS.

mixer. For each mixer there are two narrow-gage tracks running under the various supply chutes and these tracks are used by measuring car-hoppers of fixed dimensions, each hopper being filled from its appropriate bin. This arrangement of two tracks per mixer allows one hopper car to be leading while the second hopper car is dumping into the mixer.

After mixing the concrete dumps directly into 1-yd. buckets on the main delivery track below. In ordinary work the concrete train consists of eight cars, each car carrying two buckets, making approximately 16 yds. per train. These cars are handled to the work by 18-ton dinkey engines traversing well-ballasted track, at about an average of 12 miles per hr. each way.

TEMPORARY CONSTRUCTION BRIDGE.—On account of the rapidity and volume of the river and its sudden rises and floods and the debris they carry, it was found impracticable to consider the ordinary trestle construction for the support of the cranes and the trains delivering concrete to the finished work. Experience has shown that the ordinary trestle construction would have been carried away with each flood and that much extra expense and delay would have been caused by the use of temporary work. To obviate the above difficulties, a concrete construction bridge connects the concrete mill with the extreme end of the dam on the York County shore. This construction bridge is composed of arches of approximately 40-ft. spans each. The general plan and elevation of this bridge for the Lancaster shore is shown by Fig. 17. The bridge work across the Lancaster channel is approximately 1,100 ft. long, the roadway is 50 ft. wide and the foundations for the piers in front of the power-house proper are 50 ft. below the bridge deck. This structure carries four tracks of railway and the traveling cranes hereinafter described, and this particular part of the bridge work was constructed in 45 days.

The bridge across the York channel is 900 ft. long, of the same general design as shown above, and was constructed in 22 days. When all of the concrete work in the permanent structure is completed all of that portion of the concrete bridge in front of the dam will have served its purpose and will be broken up with dynamite. That portion of the concrete bridge in front of the power-house will be used as permanent foundations for the transformer house. Figs. 3 and 7 will best illustrate the labor imposed upon this bridge during flood times and will also emphasize the wisdom of using concrete construction for this bridge instead of timber or other form of trestle work.

TRAVELING CRANES.—Two types of traveling cranes are in use, each being designed in the offices of the company for the particular class of work they were to perform. Type 1, shown by Fig. 16, has a 44-ft. gage and is used on the construction bridge for all of the construction work, all excavations for the foundations of the dam and the building of the new masonry thereon. Three of these machines are used for this part of the work, two of them being for depositing concrete and the third for the erection of forms and for the performance of excavation. Each crane is equipped with four rigid inter-connected booms of the cantilever type, as shown, and each boom is 109 ft. long, the spacing of the booms being 10 ft. c. to c. The cranes have a capacity of 5,000 lbs. per boom, or 20,000 lbs. per crane at the extreme outer ends of the booms. The loads travel up the inclines of the booms suspended from trolleys, all actuated by compressed air from the four two-drum engines on the cranes.

These travelers move very freely on their own track, the movement being accomplished by the use of the work engines which haul the concrete trains. One particular advantage of this system of depositing concrete is the small amount of time (averaging here about ten minutes) that elapses from the time the concrete is mixed until it is in place on the wall.

One further advantage in this system of delivery lies in the engine man who operates the load on the crane being so close to the work that extensive signal systems and their dangers and delays are avoided, consequently the unloading of the mixture is rapidly effected and the deposit made at the exact place wanted. The fact that the load always travels in the same direction and is not slung around over a long circumference, as in the case with derricks, also contributes speed of deposit and safety to the men, as they know always where the load is going.

Two travelers of Type 2 (Fig. 10) were also built for the construction of the power-house. These travelers have a 45-ft. gage, are 45 ft.

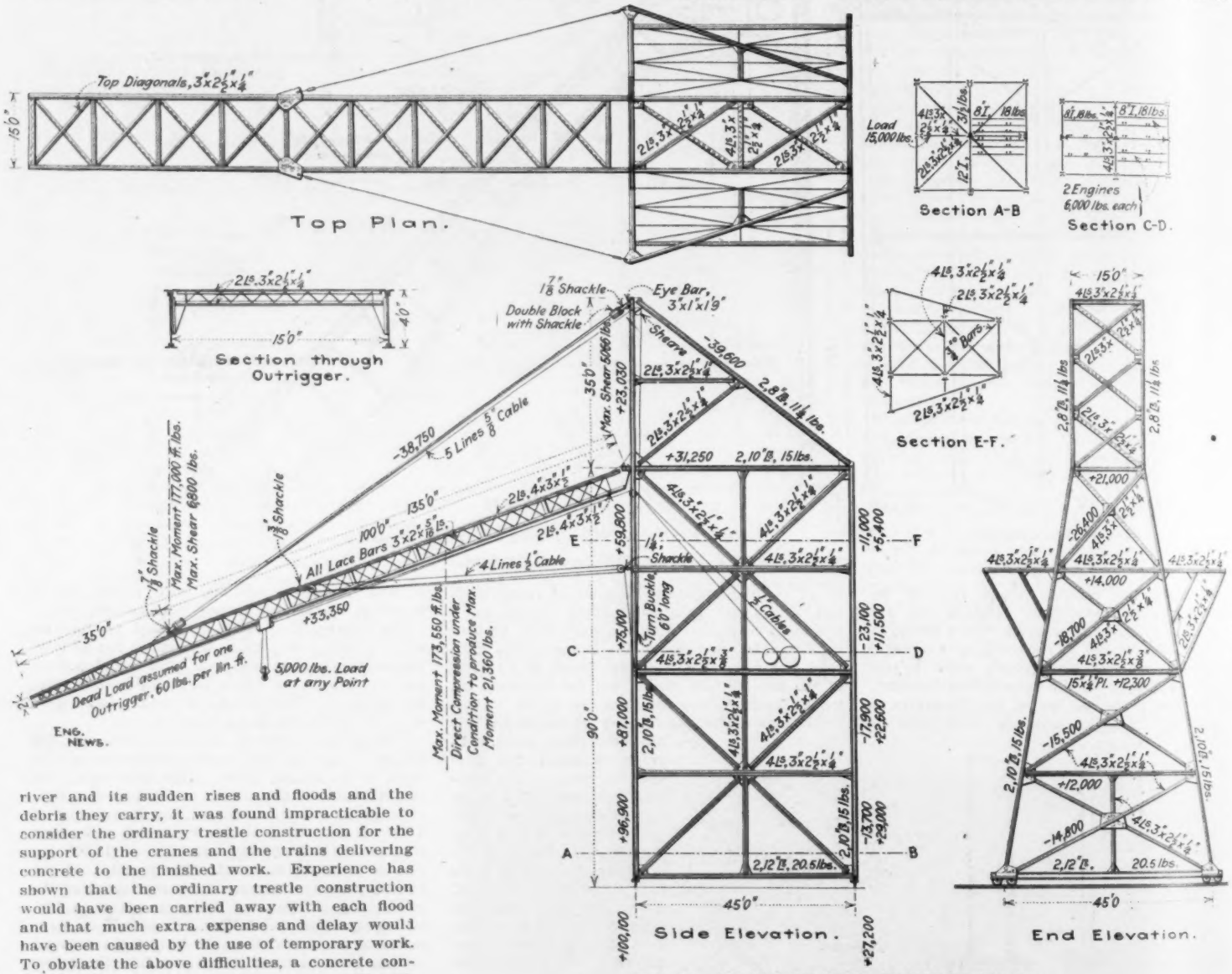


FIG. 10. DETAILS OF STEEL TRAVELER NO. 2.

wide, and measure 135 ft. from the rails to the tops of the structures. They are each equipped with two inter-connected booms, overhanging 135 ft., each with a capacity of 5,000 lbs. on the extreme point. These booms are 20 ft. c. to c. This class of traveler is also portable and works in the same general way as the travelers of the Type 1, specified above.

One other feature may be mentioned as to the value of machines of this kind: in times of flood the apparatus can be rapidly removed to a place of safety, as has been done repeatedly at McCall Ferry.

With these cranes the whole of the main work was controlled. In some of the outlying parts of the construction, it was necessary to use single-boom derricks operated by steam-hoisting en-

gines, and the western cofferdam was built by a traveling conveyor slung between the York County shore and Fry's Island.

STEEL FORMS FOR DAM CONSTRUCTION.—The forms for the dam were specially designed for ease in erection and transfer, interchangeability and strength. For these reasons, the current practice of timber forming was abandoned and the new design of an interchangeable steel form was adopted. As has been noted, the dam section was built up to an elevation about 5 ft. above the beginning of the curve, in a continuous line across the entire distance of each channel. Upon this solid continuous block the curved sections were built in alternate sections 40 ft. long and 40 ft. apart. For each one of these 40-ft. sections a separate steel framework was constructed, each identical in design and so arranged as to be available, as built, for any section of the dam in either channel, and with slight modifications on the ground for any section on the island.

These forms are shown in detail by Figs. 8 and 9 and their general position and characteristics may be well noted on many of the half tones illustrating various portions of the work. In brief, they consist of a framework of five rafters, firmly held by bolts and backing blocks to the completed lower parts of the dam, cross and counter braced longitudinally, and following in general the curved outline of the dam. The lagging against which the concrete is held is made up of wooden boxes or cradles, fastened directly to each rafter on the straight front of the dam and to curved channels held by small struts so as to form the proper curve on the overflow down-stream face. The fastenings at the bottom of the rafter, shown in detail in Fig. 9, were placed at the time of laying that portion, and having once been lined up at that time, no further transit work was required to make the alinement of the upper parts correct. The rafters are of built-up channel-column section and are cross-braced by horizontal double angles and diagonal square rods with clevis connections to plates. In order to provide for the possible need of removing the vertical front rafters, a device, shown on Fig. 8 and marked "Details of Support A," is provided by which the curved section may be supported unaided.

The details of the wooden lagging boxes or cradles are shown on Fig. 9. These were five-sided boxes, open on top, about 8½ ft. in width and 10 ft. in length, and were connected by bolts to wooden frames attached, in back, to the bottom face of the curved 12-in. channel which formed the bottom chord of the back or curved face and in front directly to vertical rafter.

FIG. 11. TAIL-RACE AT McCALL FERRY POWER PLANT. CONCRETE MIXER AT RIGHT. TRAVELERS IN BACKGROUND.

As may be seen in Fig. 5, the completed continuous section is finished to a point above the curve of the back face. The forms for this small portion of the curve were first erected and built as shown in the lower right hand portion of Fig. 8. That is, the first 30-ft. section of this rafter was erected and held back into line by the 5-in. channels shown, fastened onto bolts previously placed in correct line and grade on the temporary concrete bridge. When the work was to be commenced on the 40-ft. sections the remainder of the form was completed upon the small portion already in and the timber boxes or cradles were placed as the concrete rose in the forms. There were six sets of these forms, and simultaneous work was carried on along the entire channel under construction.

FIG. 12. VIEW SHOWING STEEL FORMS FOR DAM SECTIONS.

The work on the island section of the dam, which section is shown in diagram in Fig. 6, is well illustrated in Fig. 12. Here the curve of the overflow face is the same at the bottom reverse, but a portion of the middle parabola is omitted. The first 30-ft. section of each rafter was therefore erected here with the last small channel strut omitted, the whole framework being held back in line by steel cables attached to the construction bridge. The front face was held by wooden struts braced against the earth, which was high enough at this point for such a use. The upper part of the framework was then placed in such longitudinal position that the upper rafters just cleared the lower ones on the curved face and, projecting by them, were lashed together securely in place.

DAM CONSTRUCTION.—The ends of the 40-ft. sections were held in place by timber partitions braced securely against the steel framework. Into these bulkheads box forms were inserted (Fig. 5). These boxes left holes in the finished sections which served as bonds between the new and old sections of the dam.

In order that the completed work might have proper space for expansion and contraction at these 40-ft. joints, the outside 3 ft. of periphery of the cross-section was covered over with tar paper when the adjacent masonry was put in place. This thickness of tar paper was varied from 3-ply to 1-ply of ordinary tar paper, according to the temperature at the time the concrete was laid. The foregoing arrangement was based upon the theory that the variations in temperature are not effective on the masonry beyond 3 ft. in depth and it is expected that the tar paper will immediately decay and the joints so left will fill with deposits from the water, which deposits will be, of course, elastic. The usefulness and effectiveness of these expansion joints has been clearly shown during the construction period, joints so created in the winter having closed up in the summer to the extent of the

paper throwing off the tar on the outside of the masonry.

In the concrete of this dam, large so-called "pudding" stones were placed all through the work. These stones were of the same material as the aggregate stone (described later)—a very heavy, compact rock. They were placed as bonding stones in the top of each layer and ran from one-man stones to stone weighing as high as half a ton.

CONCRETE FORMS.—In the construction of the intake pipes, wheel pits and draft tubes, all of which are extremely complicated shapes, several innovations have been introduced. It has been customary, in previous power-house work of this sort, to make all similar openings with linings of metal, brick or masonry. As will be seen from Fig. 18, in this plant the draft tubes and intake pipes are all an integral part of the power-house; that is, they are openings inside the power-house which was built up as a whole from a clear foundation and not, as in some other works, conduits driven through the solid rock or earth above which the power-house was built. Therefore, instead of using permanent metal linings which would be used also as forms around which to build the concrete body of the power-house, wooden forms were used to shape these openings. These forms were removed when the concrete had set, leaving the intakes and draft tubes formed of solid masonry with no lining.

Figs. 13 and 15 give an excellent idea of the construction and general shape of a few of these forms. In the foreground of Fig. 15 and in Fig. 13, the form for the lower draft tube is very well shown. These forms were built with circular and oval frames placed at the correct angles to give the proper shape to the form, and lagged with 2-in. strips of basswood bent over the frames by aid of a steam bath. The immense size and smooth surface of the forms can very well be noted. All of this work was done at the carpenter shop on the work with ordinary labor taken principally from men who lived in the neighboring country and who by no means could be called skilled carpenters; in fact, very few of them had worked at the carpenters' trade at all. They were in charge of a skilled carpenter foreman, who was on the work from the start, and to whom not a little of the success in fabricating the forms was due. It is a striking example of the efficiency of concrete in complicated work.

COFFERDAMS.—The cofferdam consisted of timber cribs uniformly 16 ft. in width, wherein the length of the cribs up and down stream was made 1½ times the maximum depth of the water that was to press against them. These cribs were spaced uniformly 10 ft. apart between crib walls and were scribed to fit the bed of the river. Careful soundings for this purpose were taken from a float in each case anchored carefully in the position to be occupied by the cribs. They were provided with floors in the bottom for the purpose of holding rock to sink them and hold them in position. After the bed of the river between Fry's Island and the Lancaster shore had been filled with the cribs as above described, the 10-ft. openings left between the cribs were filled with ordinary 12-in. square stop-log timbers, the bottom stop-log being scribed to fit the inequalities of the rock which it covered. This operation of placing stop-logs was carried on uniformly across this channel, the logs being brought up practically level. When the stop-logs were in position it was found that about 95% of the water was diverted to the York channel of the stream. The remaining 5% of the water was shut off in the following manner:

The up-stream face of the cofferdam was first covered over by two lines of vertical 2 × 6-in.

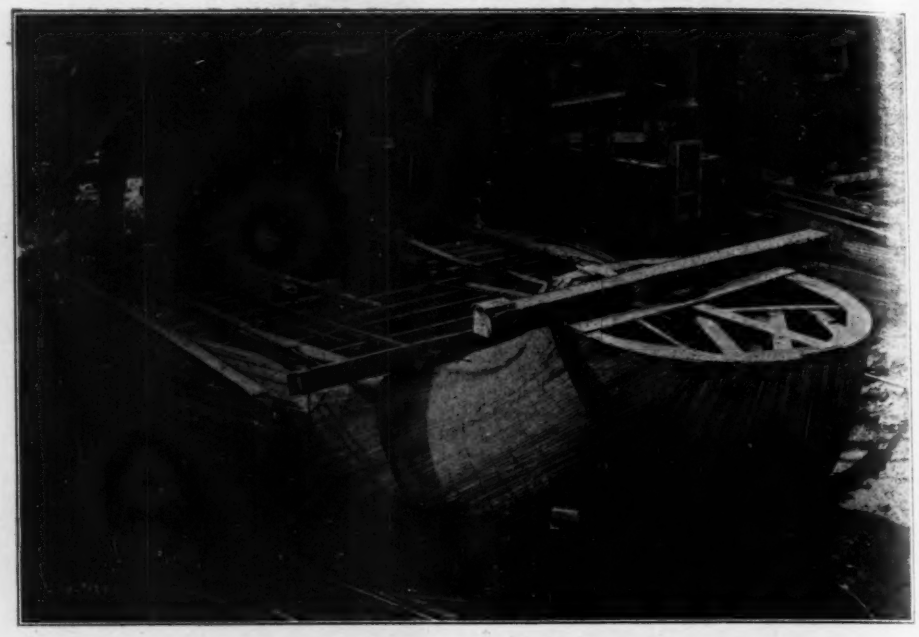


FIG. 13. WOODEN FORMS FOR DRAFT TUBES.

sheeting driven from the top of the cofferdam to as tight a fit to the bed of the river as could be possible without divers and the portion of the sheeting above the water level was spiked to the cofferdam, the water-pressure below the water surface being depended upon only to hold the sheeting against the face of the cofferdam. After this sheeting was in place, the remaining holes in the cofferdam were blocked by small bundles of brush containing enough stone weighted in the bundles to hold the brush in place in front of the holes.

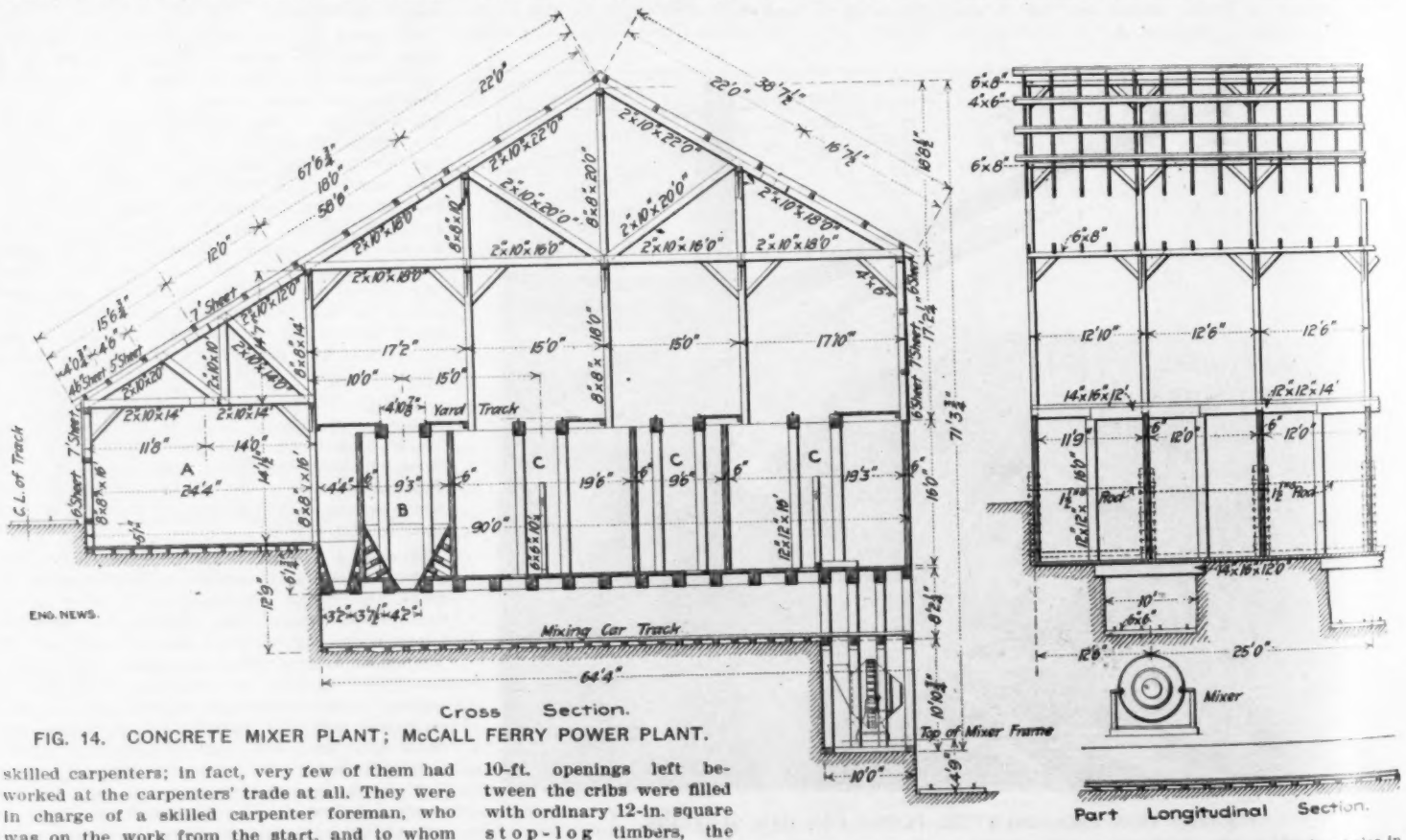


FIG. 14. CONCRETE MIXER PLANT; McCALL FERRY POWER PLANT.

The concluding operation was merely one of dumping from 6-yd. dump cars trains of puddle over the front face of the cofferdam and allowing this puddle to settle to its natural slope. The puddle material was taken from Fry's Island and

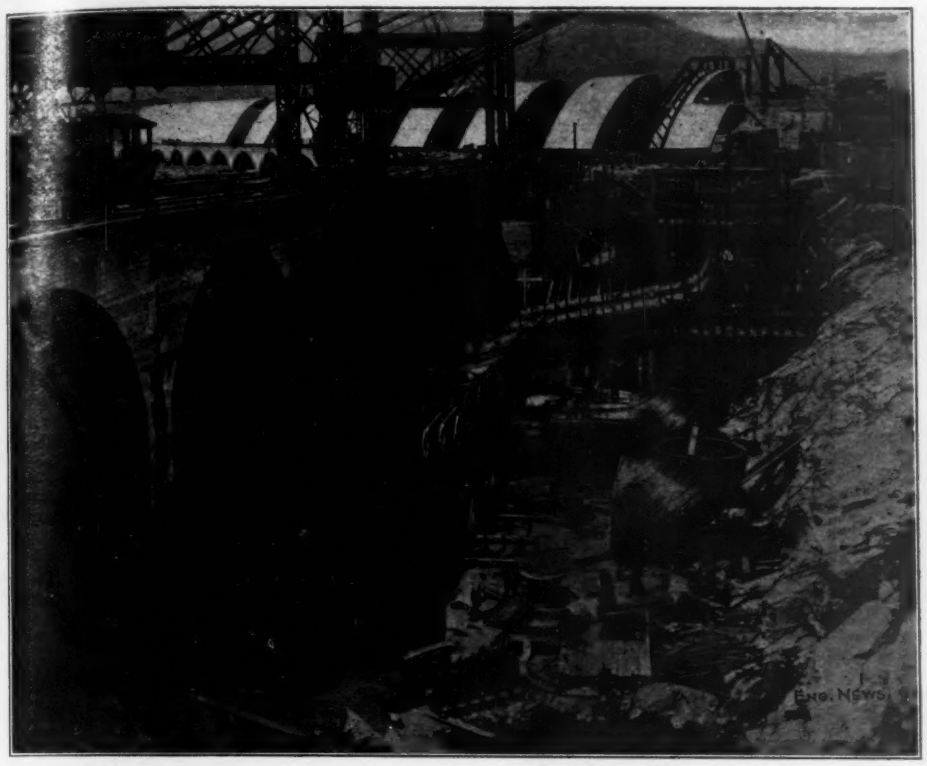


FIG. 15. FORM WORK IN PIT OF POWER HOUSE.
(Exciter intake tubes in middle distance.)

was rather heavily impregnated with sand, probably 25%, the balance of material being a light clay. This method of construction yielded a cofferdam so tight that under 18 ft. of head the leakage over a length of 1,000 ft. was only ¼-cu. ft. per sec.

This cofferdam was overlapped by floods three times during its use and at no time suffered damage. During the flood of March, 1907, the ice and water were piled up 12 ft. deep on top of it.

MATERIAL.—All concrete work in this structure is made 1 part of cement, 3 parts of sand and 5 parts of broken stone. In contrast to much concrete construction, the broken stone for the large sections in the dam and power-house has not been required to be crushed fine. The average of the stone used would have a greatest dimension of at least 5 ins.

The run of the crusher has been separated into three parts. The first part is the heavy stone required for heavy work. The second division is for material which will pass through a 2-in. screen, which has been used for the small walls throughout the work. The third division is crusher dust, which is being used in place of sand in the power-house superstructure walls. In the use of concrete for this work a sufficient amount of water has been used at all times so that the material when deposited on the wall does not require tamping and settles into its final position through the action of gravity.

This does not require a consistency approaching grout, but does require a consistency such that the material in bulk will quake when tramped on or jarred by train movement. The stripping of forms on 65% of the completed work and the drilling that has been done from time to time in the finished work all show that the voids are well filled, the faces not requiring repointing or touching up.

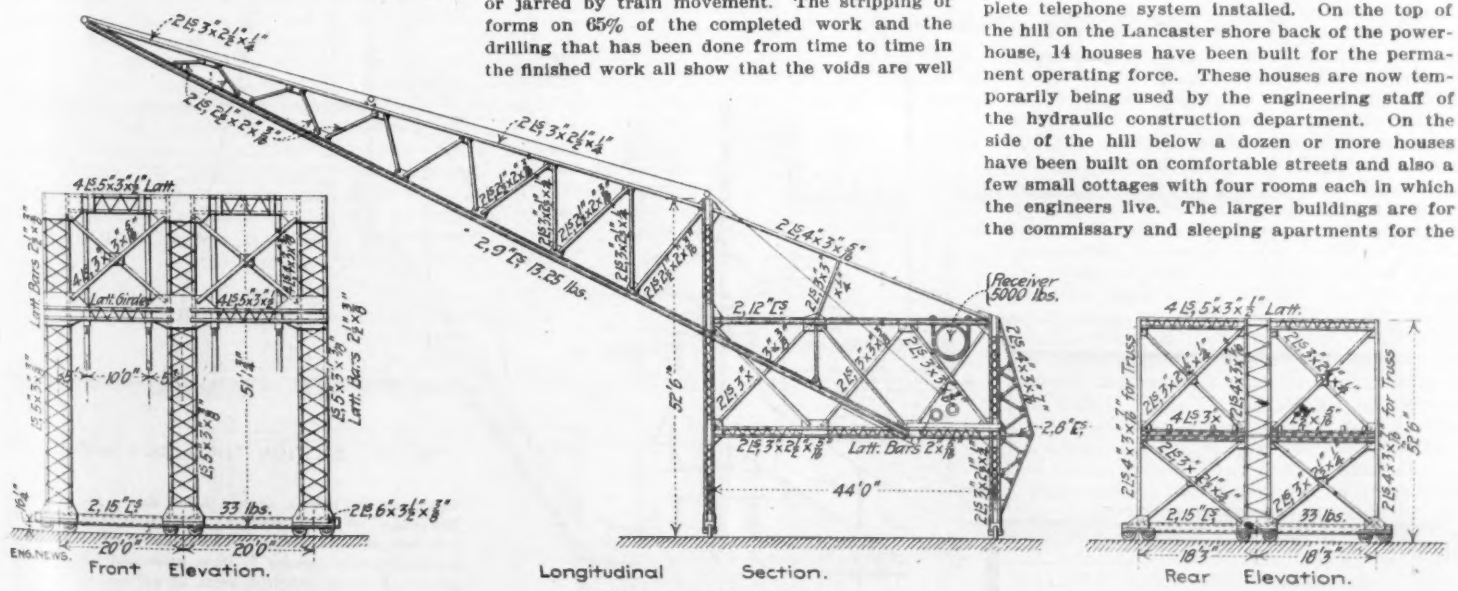


FIG. 16. TRAVELER NO. 1.

SAND.—Sand for this work comes from a sand deposit located by the engineers in the vicinity of Charlestown, Md. This sand exists in a large bank and is reached by a side track from the main line of the Pennsylvania Railroad at Charlestown. It is loaded in steel hopper cars by a Marion 60-ton steam shovel. The quality of the sand is all that could be desired for work of this kind. Repeated physical tests show that a mortar from this sand is about 30% stronger than mortar from the same cement and Ottawa sand.

STONE.—The mica existing in the rock at the dam site prevented its use in masonry. The nearest available stone deposit was found at Conowingo, Md., on the banks of Conowingo Creek. Conowingo is on the line of the Pennsylvania Railroad, 14 miles from the dam site. The stone there was found to have a remarkably high specific gravity, several tests for the weight of the stone showing a minimum of 194 lbs. per cu. ft. The rock is igneous in character, is very close grained and in the quarry surface rock shows no deterioration due to weather or temperature. This same rock is used for pudding stone in the main dam.

The quarry equipment at Conowingo consists of four 5-ton portable Lidgerwood cableways, four 5-ton quarry derricks, a compressor plant for operating the air drills, the usual complement of tripod and portable hand drills for rock drilling, together with five standard-gage locomotives operating on four miles of delivery track and their sidings. The crushing is done by the use of two No. 8 Austin stone crushers, the quarry storage capacity in the bins being 1,000 cu. yds. of broken stone.

CONSTRUCTION CAMP.—The construction camp is one of the most interesting parts of the work. Less than two years ago, when the present organization commenced operations, the surrounding country at the dam site was virgin land. Here and there scattered through the woods were stray houses, but just at the river bank where the construction camp now stands was a thickly grown forest. This forest has been removed and much of it has been sawed up into construction lumber and in its place a camp has been built for the care of upwards of 1,200 men. On account of the absence of any near-by town or city, the company in a general way has to provide for the entire force at work, and as this force was expected to be occupied for at least 2½ years, the usual contractors' construction camp was out of the question.

A small city has therefore been built. Back in the hills, springs have been tapped and water brought down to a tank reservoir. Sewer lines have been laid to the river, electric lights have been wired over the entire property and a complete telephone system installed. On the top of the hill on the Lancaster shore back of the power-house, 14 houses have been built for the permanent operating force. These houses are now temporarily being used by the engineering staff of the hydraulic construction department. On the side of the hill below a dozen or more houses have been built on comfortable streets and also a few small cottages with four rooms each in which the engineers live. The larger buildings are for the commissary and sleeping apartments for the skilled workmen. For ordinary work, foreign labor is used, about two-thirds Italians and one-third Slavs. The foreign laborers are accommodated in "Little Italy," a construction camp built about a mile below the dam. A general store operated by the company, but where the operators are not required to purchase except as they

choose, is provided for the use of the men. A well-equipped hospital with a permanent physician and two trained nurses is also a part of the equipment. The sanitary arrangements are particularly good and continuous methodic examinations of the water are made. The general sanitary management is in charge of the camp physician. As a result of the foregoing the percentage of sickness among the men has been extremely low.

Practically the only cases entering the hospital have been those due to physical accidents on the work.

ENGINEERING ORGANIZATION.—Mr. Cary T. Hutchinson, 60 Wall St., New York City, is chief engineer of the McCall Ferry Power Co. The hydraulic plant and its construction has been designed and is being executed by Mr. Hugh L. Cooper, of 60 Wall st., New York. Mr. Beverly R. Value is engineer in charge of construction at McCall Ferry.

THE ERIE CANAL at Syracuse developed another leak immediately after the repair of the first break noted in our issues of Aug. 8 and Aug. 29. The first break was finally repaired on Sept. 2, and the water immediately let into the five-mile level at that point. When 6 ft. out of the normal 9 ft. had been reached a leak developed in the canal bed, which showed as a fountain jet of water in the bed of Onondaga Creek, about under the connection made between the old stone arch and the new concrete structure. At first the leak in the bed could not be located, but later a small whirlpool developed some 50 ft. west of the arches, and soundings disclosed a hole at this point at least 20 ft. deep. Ineffectual efforts were made to close the leak with hay bales and bags of clay, but finally the water in the level was drawn off, the keystone of the old central arch being taken out to expedite the flow of water. The leak is through the new bottom made to fill the washout following the flood caused by the original break, thence under the newly made foundations of the west abutment of the west arch. The wash of the water has torn out a considerable amount of the newly made fill and the conditions at present are nearly as bad as they were three weeks ago. Twelve days before this later break, when a representative of Engineering News examined the repair work, the fill on the washed-out slope had not been made for a distance of 50 ft. west of the break, the north canal wall was still in ruins for a length of about 75 ft., and pile-drivers were at work in an effort to drive footing piles through the old foundation timbering under the west abutment. (See Engineering News, p. 219, Aug. 29, 1907.) This pile-driving was causing considerable trouble, owing to the thickly interlaced timbers which formed the footings for the old masonry arch. The subsoil here was gravelly and quite pervious to water. Since that time the slope fill has been made, the canal wall completed, a 25-ft. concrete arch, about 60 ft. long, and founded on a heavy concrete footing, built and connected into the faces of the old masonry arch, and some 3 ft. of fill made over the bottom of the canal for a distance of 150 ft. or more. It would seem as though the pressing need of through traffic in the canal had made speed in construction the prime consideration.

THE RAILWAYS OF INDIA aggregated 29,303 miles in operation at the end of March, 1903, with 3,150 miles under construction and authorized. The first annual report has been made by the new Railway Board appointed by the government to manage the railway affairs, as noted in our issue of Aug. 23, 1906, and is for the calendar year 1906. Practically all the railways are owned or controlled by the government, and many of them are also operated by the government. During 1906 there were 792 miles of new line opened and [illegible] authorized, and at the end of the year 29,097 miles were in operation, as follows: 15,548 miles of the 5 ft. 6 ins. standard gage, 12,149 miles of meter gage, [illegible] miles of 30 ins. gage and 329 miles of 24 ins. gage. The equipment includes 6,045 locomotives, 21,053 cars in passenger service and 115,336 in freight service. Of these, 3,419 locomotives, 11,700 passenger cars and 5,149 freight cars are fitted with automatic brakes. Of the passenger cars, 10,204 are lighted by gas and 1,535 by electricity. There are 4,717 stations, with interlocking plants at 1,235 and block signal equipment at 1,168. The number of persons killed in accidents to trains and along the lines was 1,614 (164 passengers), with 1,494 persons injured (562 passengers). The large majority of those killed were trespassers or suicides. The bulk of the employees are natives; these aggregate 463,108 as against 6,850 Europeans and 9,326 Eurasians (or half-breeds). A large amount of work has been done in strengthening bridge superstructures on account of the increase in train loads and weight of engines. A much disputed point at present is as to the future development of the meter-gage lines, which at present form isolated systems. One proposition is to build extensions to link them up into a comprehensive system, but this involves great complication and trouble in reaching important points on the standard-gage lines. The other proposition is to widen the gage and eventually have one great system of the uniform gage of 5 ft. 6 ins. The latter appears to be by far the better plan, especially in view of the importance of the railways of that country for military and strategic purposes.

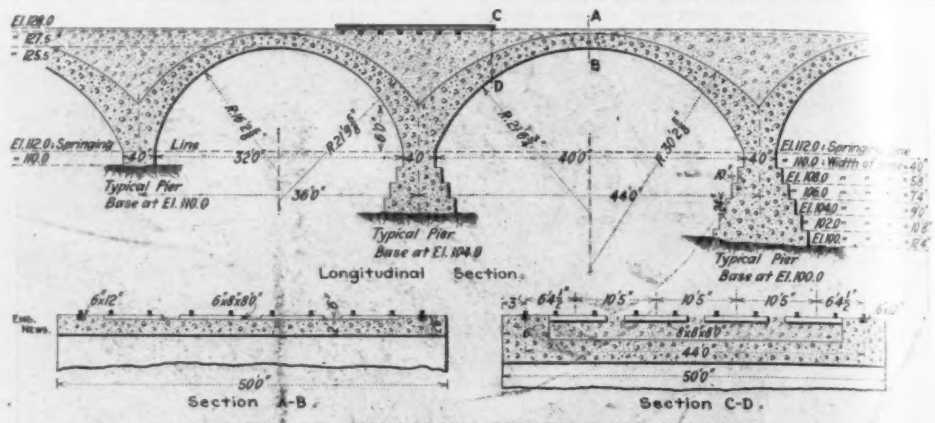


FIG. 17. TEMPORARY CONSTRUCTION BRIDGE.

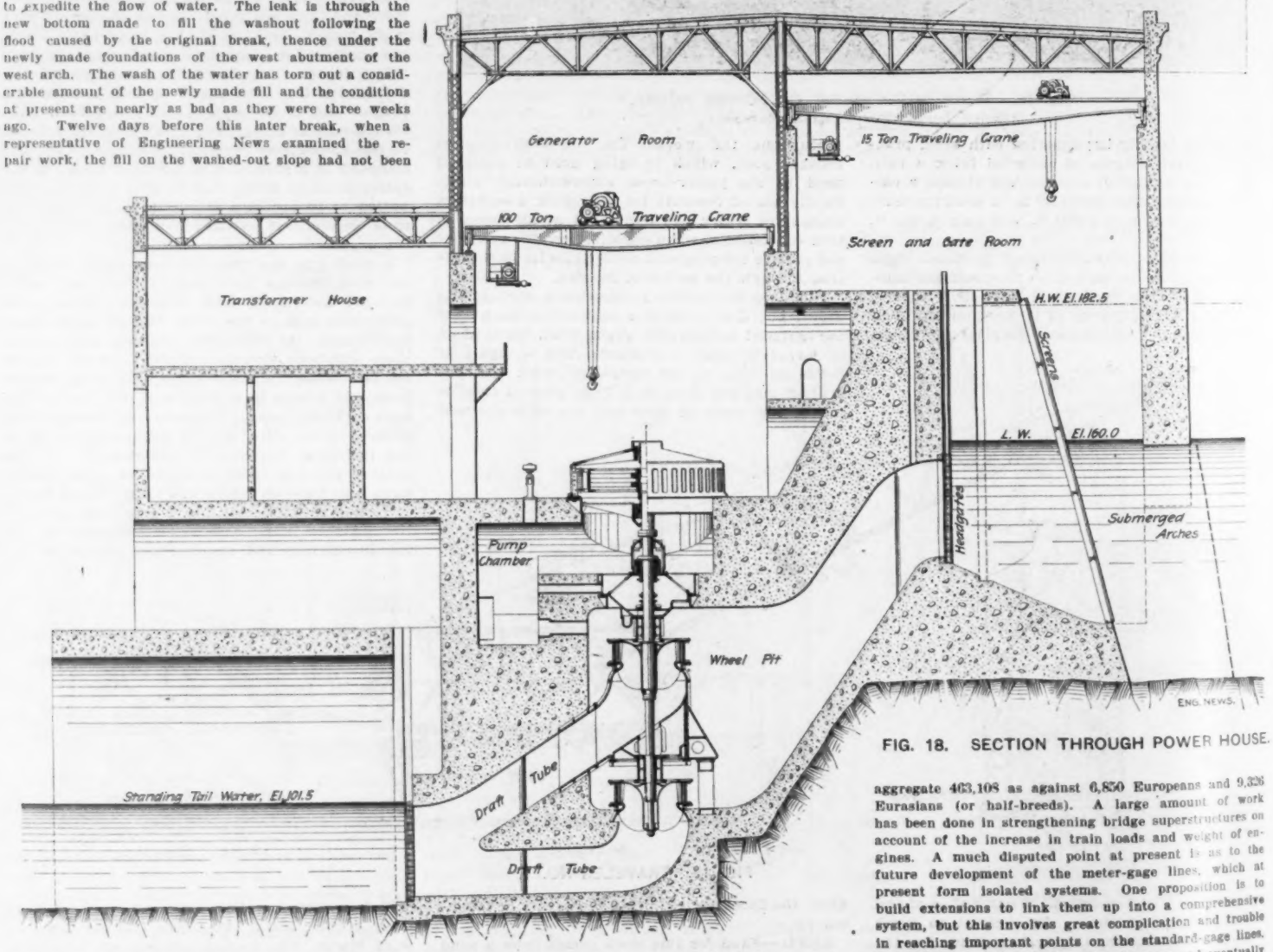


FIG. 18. SECTION THROUGH POWER HOUSE.

A STRIPPING EXCAVATOR WITH A CONVEYOR TO FORM THE WASTE BANK.

An interesting combination of excavating and conveying plant has recently been built to meet special conditions involved in the stripping of coal lands. The Consumers Coal Co., of Danville, Ill., awarded a contract to G. W. Prutzman, of the same city, to strip 35 acres of coal lands, the work involving the removal of 38 to 40 ft. of overburden. Of this depth, 16 to 24 ft. is shale and the balance gravel and clay. It was required that this should be excavated to the full depth at one cut, and all the material placed to one side, leaving a bottom width of 36 ft. of clean coal, ready for removal. It was essential that the cost of the work should be kept as low as possible, and under the conditions of character of material and depth of cut it was considered that with steam shovels served by engines and dump cars the cost could not be kept within the required limit.

A special excavating machine, with conveyor attachment, was designed and built by the Bellefontaine Foundry & Machine Co., of Bellefontaine, O., and we are indebted to that company for the accompanying information. The essential points to be covered by the design were as follows: (1) The excavator portion of the machine should have a speed of operation equal to that of the largest steam shovel, with ample power; (2) The disposition of the material required a second handling of about 80% of the material; this delivery should be continuous and practically automatic, and require no cable in addition to that required for an ordinary steam shovel. (3) The reach or working radius of action of the excavator should be sufficient (without sacrificing speed) to enable the operator to cast all large boulders, logs, etc., directly into the pit when the coal has been removed.

The machine built to meet the above conditions is shown in the accompanying view. It is in effect a steam shovel with a belt conveyor on a lateral boom. The deck or platform is 56 x 30 ft. The machine is mounted on four trucks, moving on two tracks composed of short rails laid loosely on the ties and connected by bridle bars. The forward trucks are at the immediate front end, while the rear trucks are set about 8 ft. from the rear. To allow for inequality of the coal surface on which the tracks are laid, each truck has one swivel axle, so that the load is carried on three points, while at the same time it is distributed equally on the wheels. The entire car body has also a three-point support on the four trucks, the rear end being carried by a 5-in. king pin in the center of a transverse bolster or equalizer which rests on the two rear trucks. The truck frames are substantially built. The wheels are 30 ins. in diameter and weigh 900 lbs.; each has double flanges 2¼ ins. thick, strong enough to crowd the rails of the two tracks into proper relation to each other. When making short curves, one or two of the rails are laid directly on the ties and the others on steel plates on the ties. Large center plates on the body bolsters engage with sockets in the truck bolsters. The trucks can be swiveled sufficiently to turn the entire machine at right angles in less than twice its length, if desired.

The builder's standard double-cylinder engines are used for all the movements of the excavator. The hoist engines have cylinders 10 x 12 ins., driving the drums through heavy steel gears with a ratio of 5.75 to 1. The drum usually termed the backing drum is used for hoisting or changing the elevation or angle of the elevating conveyor, but it has no connection with the handling of the bucket. The drums are of three-part construction, so that the barrels can be readily changed if desired. The usual steam clutches are used, with outside bands having wood lining. The swinging circle is 12 ft. in diameter, and is operated by an 8 x 8-in. throttle reversing engine. An engine of the same size and style, built on a cast steel bed, is fitted upon the boom as a thrusting engine. The conveyor and its feeder are driven by an 8 x 10-in. single-cylinder engine. Steam at 125 lbs. pressure is supplied by a 100-HP. boiler of the locomotive type, 5 ft. diameter and 21 ft. long. All the machinery is enclosed within a cab or housing the full size of the car body.

The boom is 35 ft. long, c. to c., and is of steel and wood construction. The dipper handle is of the same style of construction, 24 ft. long, and fitted with a heavy steel rack. The 2-yd. dipper is built entirely of wrought and forged material, and is fitted with four heavy teeth. It is handled by a 1¼-in. chain, and is attached to the handle with the solid rigid socket type of connection, which was considered preferable to the pin and bar connection. Ample fixed amount of rake is provided in the socket construction.

The excavated material is dumped by the dipper into a large steel hopper at one side and near the front end of the machine. From the bottom of this hopper it is carried at a uniform rate and depth by a steel cross-feeder about 12 ft. c. to c. to a small hopper at the lower end of the elevating belt. This is a 40-in. belt, running on a steel truss boom 105 ft. c. to c., supported by a topping lift from a tower 48 ft. high above the deck. The dumping clearance at the outer end of the conveyor is nearly 60 ft. above the track. In the ordinary operation of the machine, with the 24-ft. dipper handle, all very heavy or large pieces, stumps and logs are easily cast directly from the dipper into the space from which the coal has been removed. In order to steady the machine and prevent oscillation or vibration while at work there is a jack at each side, just behind the front truck. This is not carried by a projecting jack arm, but is attached directly to the underframe, and rests on the track. There is no propelling mechanism, but the machine is easily moved in either direction by means of steel rope tackles hooked directly into the back of the dipper. Forged clamps, which seize the rails just back of the forward trucks, serve as hitches or anchors. Changing the forward and rear blocks from truck to track reverses the direction of the car when pulling at the dipper. This is said to be an extremely powerful mode of moving the car. With no chains, sprockets, clutches, etc., on the axles, the trucks are free to swivel to any desired extent.

This machine has been tested on what is considered to be the heaviest and roughest stripping for coal ever attempted. While it was originally designed for this class of work, there are many large earth-handling operations to which it can be applied. The builders therefore propose to build it in two sizes: the larger one with a 2-yd. bucket for hard material and deep cuts, and the lighter one with a 1¼-yd. bucket for lighter material and cuts. The length of the conveyor boom on either size would be made to suit the depth of the material to be handled, but the length of the elevator is independent of the speed of excavation.

A STRIPPING EXCAVATOR WITH BELT CONVEYOR TO FORM THE WASTE BANK.
Bellefontaine Foundry & Machine Co., Bellefontaine, O., Builders.

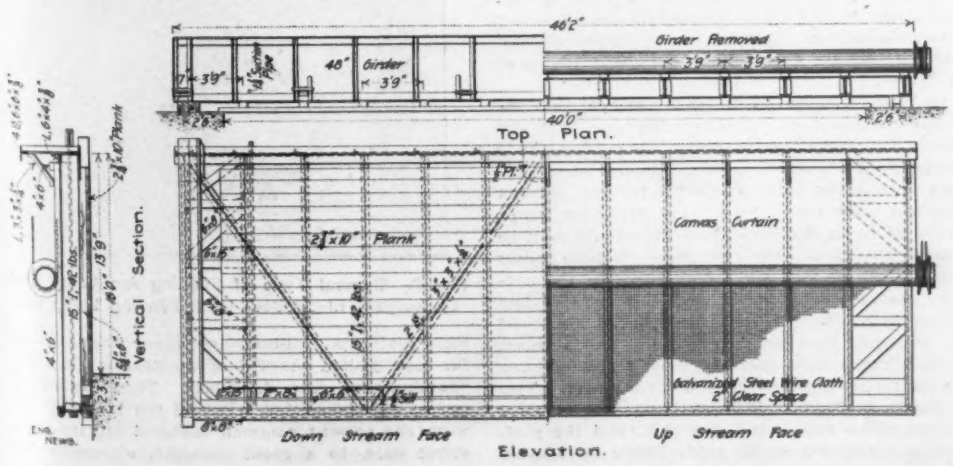


FIG. 19. STOP CURTAIN USED ACROSS EACH OPENING IN DAM AT McCALL FERRY POWER PLANT.

RECENT ADVANCES IN ARTIFICIAL LIGHTING.

ARC AND VACUUM-TUBE ELECTRIC LAMPS.

In a previous issue* the advance of artificial lighting, due to new light-sources best adapted to interior illumination, was described. It is intended in this article to consider the recent developments in those lamps whose widest use is out-doors or in very large interiors.

LIGHT FROM GASES AND VAPORS.—Whenever a gas or a vapor is made luminescent, certain definite wave lengths of light are always given off and a definite spectrum is always obtained for each gas or vapor. When the atoms or molecules of a gas or vapor are caused, by electrical means, to move in such a manner that light is produced, heat also is produced as a result of the electrical conduction; but the temperature is not related to the quality of the light except in the case of metallic vapors, when a certain temperature may be necessary for the existence of the vapor in quantity. This phenomena is the reverse of that generally observed in the case of incandescent solids, where the light is directly related, both in color and amount, to the temperature. Gases and vapors may be made luminant by electrical stress in vacuum tubes and by electric arcs.

DIRECT AND ALTERNATING CURRENT ARCS.—The spectrum of an arc is that of the vapor of the negative electrode, and is independent of the material of the positive electrode, except as materials held therein enter the arc vapor as a result of the high temperature attained. An arc is essentially a direct-current phenomena, and except under definite conditions cannot exist with an alternating E. M. F. Even when so existing, the alternating-current arc is formed by a succession of separate direct-current arc streams. At the end of each half wave length, the current dies away, and with it dies the vapor stream. The next half wave of E. M. F. having a reversed direction necessitates that the current, and therefore the vapor stream, should pass in the reverse direction from that of the first half wave length. The continuity of the arc to the eye is broken if the supply voltage is not high enough to cause a current to pass through the residual vapor between the electrodes. The voltage required to jump a spark across the gap between terminals decreases with an increasing temperature, while the voltage across an arc increases with the arc temperature and therefore with the boiling point of the electrode material. Now with electrodes of certain materials the voltage across an arc becomes equal and even higher than would be required to jump a spark between the electrodes at the temperature of the residual vapor. Such electrodes allow the apparently steady maintenance of an arc between them with alternating current. The arc streams, however, are separated and continually reversing with a frequency corresponding to that of the supply current. The stroboscopic effects of alternating current arcs are the result of this reversal of vapor streams. Carbon is such a material as above described, and the development of an alternating-current lamp from the old direct-current types was possible without much experimenting and before the theoretical considerations for the maintenance of alternating-current arcs were thoroughly understood or widely appreciated.

The old direct-current lamp was first improved by enclosing the electrodes in a more or less air-tight globe. This reduced the consumption of carbon electrodes and the cost of attendance, but at the expense of efficiency of actual illumination. The esthetic effect was materially improved by the diffusing action of the enclosing globe. Where once it was possible to see only the old open arc itself, on account of its great intrinsic brilliancy, with the enclosed arc it became possible to distinguish the environment.

The use of the enclosed arc has become so common that the lamp need not be further considered here. Indeed, there is promise that it will be superseded by a newer type of arc-lamp hereafter described.

*Engineering News, July 25, 1907.

LUMINOUS ARCS.—In an ordinary arc between carbon electrodes, the light comes from the tip of the incandescent electrodes, and comparatively none from the vapor stream itself. In the development of the new lamps it was attempted to increase the light-giving power of this non-luminous vapor by introducing some substance not carried by the common carbon electrodes. There are two ways of doing this: (1) by using in a direct-current lamp negative electrodes of a material whose vapor gives a highly-luminous spectrum; (2) by employing electrodes of such refractory materials as will give a very high arc temperature and cause to be fed into the arc vapor, by heat effects, materials which may be carried by the positive electrode, but which are not serviceable for the material of electrodes of the first class, though increasing the light-giving power of the vapor. Lamps working on the latter scheme are universally known as "flaming arcs," while those working on the first idea are variously called "metallic," "magnetite," "titanium," or even "luminous" arcs.

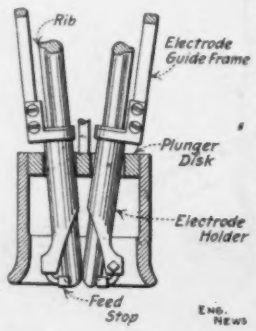


Fig. 1. Lower Mechanism of Flaming Arc Lamp; Beck Flaming Lamp Co.

THE FLAMING ARC.—Carbon arcs have proven refractory enough to secure the temperature necessary for vaporizing the foreign substances which it was desired to introduce into the arc vapor to increase the light. If we have a carbon negative and a positive of carbon impregnated with or containing a core of calcium fluoride or borate, then the calcium vapor enters the arc vapor and is heated to the arc temperature, becoming highly luminous. Such material is preferably so fed in from the positive electrode, as this is the hotter. Here the efficiency of light production depends on the temperature of the positive electrode which controls the vaporization of the luminescing material. If the positive electrode is large and consumes but slowly, the efficiency decreases as the amounts of luminescing material evaporated is necessarily smaller. Therefore a rapid consumption of the positive electrode is necessary. This positive electrode may be of a good grade of carbon, with a core of the calcium salts. Often the core becomes so large that the carbon is a mere outer shell, and in this case the salts must be mixed with considerable carbon for necessary conductivity. The arc flame of these lamps, used with direct current, takes a more or less distorted conical shape, having its base about the positive electrode. This flame has a brilliant luminous core of the arc stream proper, composed of the decomposed vapors of the calcium salts. About the arc stream is the zone in which the materials are recombining with oxygen, fluorine, etc., and around this zone is the slightly opaque cooler products of recombination, in a finely divided form, giving the appearance of a slight smoke or of fumes.

In some American-designed lamps the familiar arrangement of electrodes, one over the other, is maintained. Many American-made lamps, in fact, those most commonly seen, employ converging electrodes with the arc playing between their tips. As a type of these lamps those made on the Beck German patents may be briefly described. The electrodes of these lamps carry a rib or long fin, which supports the carbon, resting on a metal stop. As the carbon burns away the rib, of course, burns also, and the electrode feeds by gravity. The arc is drawn by a plunger disk, operated by a series magnet, which forces the electrode holders apart. This is shown in Fig. 1. In some lamps the negative carbon alone rests against a stop, and the positive is suspended in its guide frame by a compensating chain attached to the negative, so that, as the latter burns away the positive also is lowered. In some forms, also, the rib on the carbon is absent. A starting resistance (or an inductance-coil in the alternating-current types), is included in the circuit to avoid a dead short circuit in starting. In some lamps magnetic blow-out coils with properly located cores repel the arc downward from the electrodes in a fan or bow. In all these forms the mechanism is very simple. The general appearance of the converging electrode type is shown in Fig. 2. The diameter of the electrodes for all flaming arc lamps is necessarily small in order that the supply of luminous vapor may be properly maintained. This, with the necessity of an open arc, makes the life of a single trimming limited from 8 to 17 hrs., the latter figure being possible with very long electrodes.

The application of flaming arcs has been more extensive in Europe than in America, on account of greater cost of current and a lower cost of carbons and labor in all the European countries. Their widest use in this country is in situations where their brilliancy may attract attention.

The flaming arc lamp may give, at about 400 to 550 watts power consumption, a mean spherical c. p. of, roughly, 850 to 1,100, a maximum downward c. p. of 1,800 to 3,300, and a mean lower hemispherical about 1,600 to 2,000 c. p. This yields a power consumption figure of about 0.7 to 0.4 watts per mean spherical candle, English Units. These figures are given from an analysis of curves and figures issued by various manufacturers, and are to be taken as indicating only approximately the lamp performance which depends to a great extent on the size, thickness and quality of the lamp globe.

METALLIC-ARC LAMPS.—The development employing negative electrodes made from materials giving a brilliant arc vapor seems to be far less limited in field of application than the "flaming-arc" just described. The possibilities are so promising that it would not be surprising were the present common enclosed arc lamp for street uses, to a great measure, superseded by these lamps on account of somewhat higher ef-

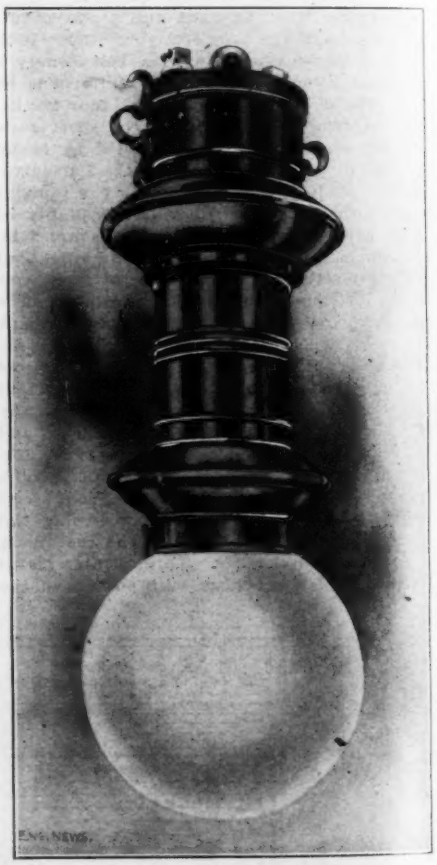


Fig. 2. General Type of Flaming Arc Lamp with Convergent Electrodes; Beck Flaming Lamp Co.

ciency and smaller maintenance expenses. A directly comparative and complete series of tests showing the relative utilities and efficiencies of the "metallic," "open" and "enclosed" types of arc lamps is not available, and only rather general comparisons can be made. Metallic arc lamps giving about 650 to 700 c. p. maximum on 310 watts energy supply, have been used to replace enclosed arc street arcs of 400 to 600 maximum c. p. on 480 watts, with improvement in the street illumination.

The manufacturers of arc lamps claim that the common demand is for street lamps giving a white light. Such a demand, at present, limits the use of substances available as negative electrodes to those whose vapor spectrum is fairly well distributed and whose light is necessarily "white." These substances are of the iron group —iron, titanium, tungsten. The range of substances is narrowed still further when the characteristics of the electrode are considered: (1) it must be a fair conductor, and (2) it must be long-lived. These necessitate the use of an oxide or a carbide. As these materials, after vaporization, redeposit as a solid, the lamp must be arranged as an "open" arc, with special ventilation.

The researches of Dr. C. P. Steinmetz showed that magnetite or magnetic iron oxide (Fe_3O_4) was the most convenient and available basis for an electrode, though its light-giving quality was inferior. The addition of a certain amount of titanium oxide gives great brilliancy and efficiency to the arc. A certain predetermined amount of chromium oxide is added, which has

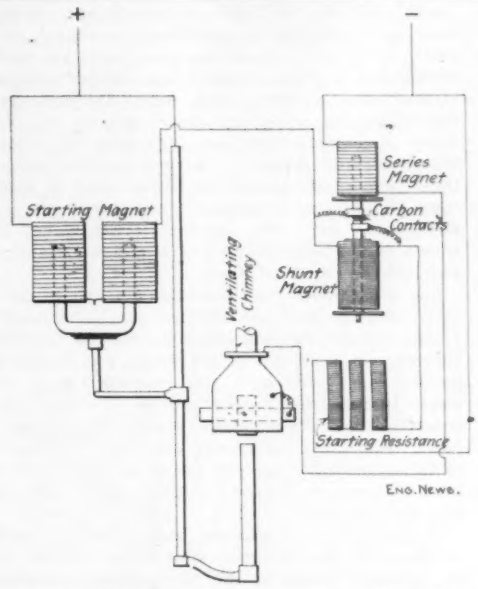


Fig. 3. Diagrammatic Arrangement of the Parts of the General Electric Type Metallic-Arc Lamp.

sumed only very slowly. At first this may seem anomalous, but the explanation is simple. As this lamp arrangement is adapted only for direct current, the arc stream is always uni-directional and toward the positive electrode. No material is carried, therefore, from the positive by the

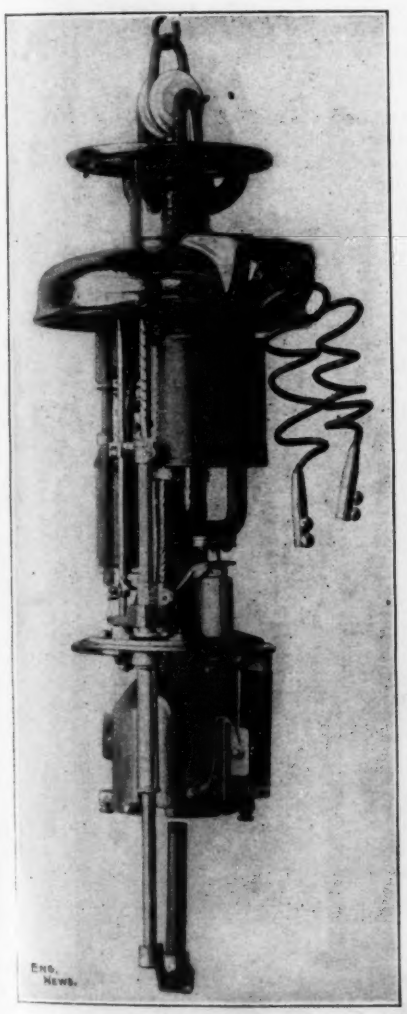


Fig. 4. Casing Removed.

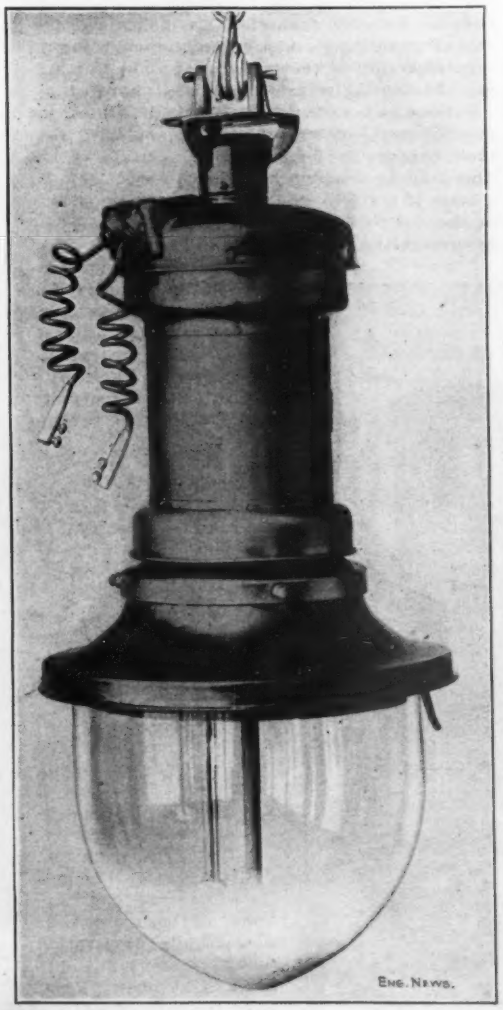


Fig. 5. Casing in Position.

FIGS. 4 AND 5. THE GENERAL ELECTRIC METALLIC ARC LAMP ASSEMBLED.

the effect of restricting undue production of titanium vapor and consequently promotes a longer life of the electrodes, although at a slight sacrifice in the efficiency of light production.

The positive of this kind of lamp is a metal, usually copper or a copper alloy, which is consumed only very slowly. At first this may seem anomalous, but the explanation is simple. As this lamp arrangement is adapted only for direct current, the arc stream is always uni-directional and toward the positive electrode. No material is carried, therefore, from the positive by the arc-stream, and if the material and design is properly manipulated the heat at this positive will be transmitted and radiated as fast as developed. A slight coating of conductive slag also protects the hottest portion of the metallic surface from rapid oxidation.

Laboratory or experimental alternating current magnetite-arc lamps have been built. Magnetite, titanium and most other metal oxides are such electrode materials as require a sparking voltage, at the temperature of the arc vapor, considerably in excess of that required to maintain an arc. This phenomenon was noted in the general discussion of arcs. On account of this characteristic of the direct-current luminous-arc electrode, they do not allow a steady arc to be maintained on alternating current. Theoretically it should be possible to construct an alternating current lamp with two oxide electrodes and a single copper negative electrode. This would work on the principle of the mercury-arc rectifier. However, titanium carbide is one of those materials which will permit of a steady arc on alternating current. It is not as incombustible as magnetite or the metallic oxides, but is stable enough to promise future development. Here each electrode acts alternatively as positive and negative, and a non-burning positive of copper or alloy cannot be used, as in the direct-current form.

The commercial form of magnetite-arc lamp has been developed on two distinct lines in this country: the one with the negative electrode above the positive, the other with these relative positions reversed. The exponents of each line of development claim especial advantages of each arrangement.

The general appearance and arrangement of parts of the General Electric underfed lamp is shown in Figs. 3 to 5.

When the lamp is started the current passes through the starting or feeding magnets and the carbon contacts of the series and shunt cut-out coils, through the starting resistances to the line. The "starting" or "feeding" magnets lift up the negative electrode until it touches the positive, when current must flow through the electrodes and the series cut-out magnet, as indicated by a glance at Fig. 3. This weakens the feeding magnets until the negative electrode falls, until supported by a clutch, thus drawing the arc. When the negative electrode is consumed so that the arc-voltage has reached a certain point the shunt-feeding magnet becomes strongly energized enough so that it closes the carbon contacts. The starting magnets are now again taking current and bringing the electrodes into contact. The lamp will now repeat the first operation. This action also tends to break up any slag or crust formed about the edges of the negative electrode. It will be noted that here the use of air currents is utilized to carry off the light solid products of the arc and incidentally to steady and center the arc.

Without such a ventilating system the accumulation of these oxides is rapid and interferes with the proper distribution of light.

The brighter portion of the arc is near the negative electrode, and the makers of the overfeed type claim that the shadow under the underfeed lamp is larger and denser than when the electrode is fed from the top. This underfeed necessitates a larger globe and a thicker electrode or a shorter life than the upper feed. With the overfeed lamp developed by the Westinghouse Co., the difficulty of the light oxide accumulating very rapidly has been obviated by arranging the ventilating system so that a current of air comes down around the negative electrode, and another scours over the reflector surface, and these both pass up a chimney, substantially as shown in the diagram, Fig. 6. It is stated that these air ducts have been carefully designed so that the highest winds cannot reduce or reverse the drafts. The steadying effect of these air currents makes it possible to maintain the arc voltage more uniform, thereby increasing the efficiency by reducing the average of watts consumed.

The general arrangement of the parts of the Westinghouse lamp are shown in Figs. 6, 7 and 8. The electrodes, when the current is off, are separated, and the cut-out contacts are closed. The armature of the feeding magnet is connected to a dash-pot having a graphite self-lubricating plunger which is designed so as not to stick under the most severe conditions.

When the current is turned on it energizes the feeding magnets, which pull down their armature and bring the electrodes into contact. This allows current to pass through the series magnet and the series cut-out is lifted from the shunt

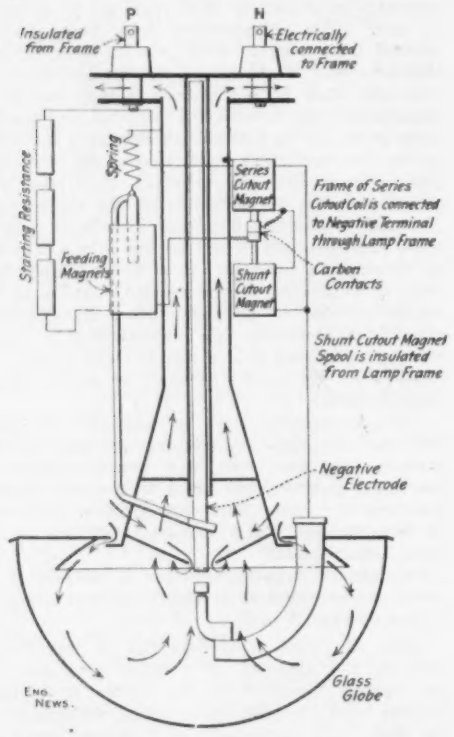


Fig. 6. Diagrammatic Arrangement of the Parts of Westinghouse Metallic Arc Lamp, Showing Direction of Air Currents.

cut-out contact, thus breaking the circuit through the feeding magnets. Accordingly the armature is released and the arc is drawn. As the negative electrode burns away the arc lengthens and the voltage across its terminals rises until a sufficient current passes through the shunt magnet so that it raises the shunt cut-out contact until it touches the series contact. Then the feeder magnets are energized and the arc fed until its normal length is re-established.

Fig. 7. With Cover Raised.

Fig. 8. With Cover Closed.

FIGS. 7 AND 8. THE WESTINGHOUSE METALLIC ARC LAMP ASSEMBLED.

RECTIFIER SYSTEM. — Metallic-arc lamps were first operated by modifications of the old-style, series arc generators, notorious for their inefficiency. After considerable experimenting, mercury-arc rectifier sets were designed for furnishing the necessary direct current at constant amperage from constant-potential alternating-current supply. The set consists essentially of a constant-current transformer, a mercury rectifier, a switchboard, and necessary instruments, etc. The general arrangement is shown in the diagram by Fig. 9 and a view of a switchboard panel by Fig. 10.

The constant-current transformers are, in general, the same as those developed for series alternating-current lighting systems. In the General Electric Co.'s system a reactance coil enclosed in the same case with the transformer is inserted in the direct-current circuit to reduce the pulsations in the rectified uni-directional current. Additional inductance also may be placed in the alternating current circuit of the rectifier tube to dampen "kicks" in that circuit due to line disturbances.

In this system a starting transformer is used to supply a low-potential split-phase current to the starting anode of the mercury-arc rectifier. A small auxiliary arc is started which ionizes the vapor of the tube and allows the main arc to establish itself at once without the high voltage necessary to start the arc between the main electrodes.

In the Westinghouse mercury-arc rectifier system the constant-current transformer is designed so that there is self induction enough in the windings to store a sufficient amount of energy so that the fluctuations of the pulsating direct-current may be properly damped. This makes the current through the rectifier constant enough to prevent flickering of the street lamps. In this system the starting transformer, also, is omitted.

To secure a satisfactory length of life of the mercury-arc rectifier tubes, it is necessary that their temperature be kept within certain values. This may be accomplished in two ways: (1) By a blast of air delivered through a proper opening in the switchboard, from a blower set. (2) By immersing the mercury-arc tube in a bath of oil so designed that the convection and conduction keep the temperature at proper values.

It is not necessary here to present a description of the mercury-arc rectifier itself or a discussion of its well-known principles. For this system some minor mechanical modifications of the tube have been found desirable, so that it does not resemble the older styles. Under normal conditions a tube life of about 700 hrs. has been attained.

The General Electric system has been installed in Poughkeepsie, N. Y., for about two years, and has proven highly satisfactory. As this is a typical installation a few points of interest may be given. At a first glance it might seem that the city was using old open arcs, but a moment's observation shows important differences at once. First, while the light of a street lamp seems intense, yet it lacks the harsh glare of the old open arc, and it is soon noted that one can distinguish objects beyond the lamp far more than could be done with the open types, and nearly as well as with the enclosed arcs. Tests show that the maximum reading distance is 25% farther from the arc than with enclosed arcs, and the distribution is fairly uniform as the lamp is approached. The shadows are sharp, but the unusually harsh contrasts of the older open-arc systems are absent. Then, again, there is a pleasing steadiness in the light.

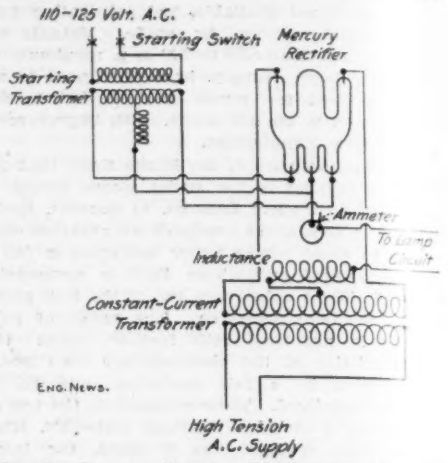


Fig. 9. Diagram Showing General Arrangement of Mercury Arc Rectifier System for Series Metallic Arc Lamps; General Electric Co.

The Poughkeepsie installation is open to a single criticism—that the globes are not sufficiently sand-blasted. This gives opportunity for two improvements: the general diffusion could be bettered and the nearer shadows softened. The small and brilliant areas could be further pre-

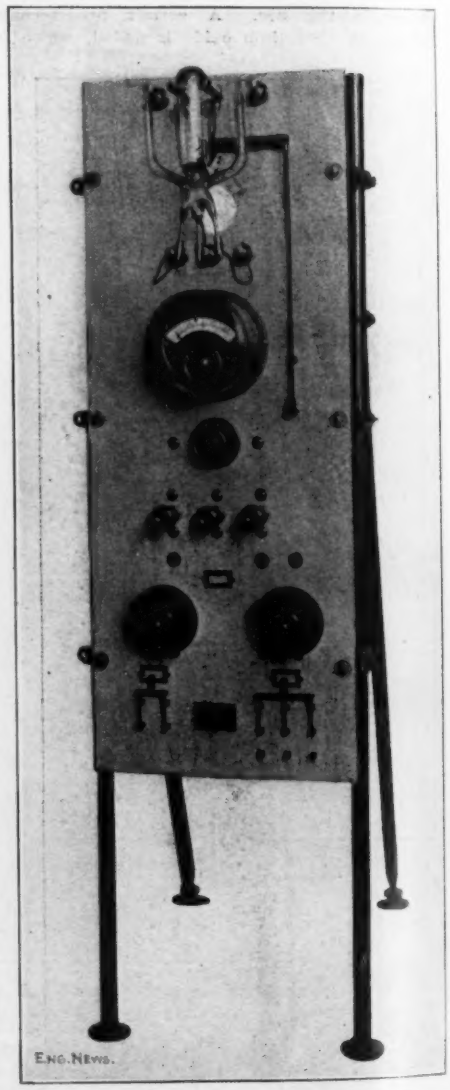


Fig. 10. Switchboard Panel Arranged for Mercury Rectifier System for Series Metallic Arc Lamps; General Electric Co.

vented from being impressed on the retina of the eye, lessening the local fatigue and unpleasant strain noticed by sensitive eyes, at least. The accompanying table shows some interesting comparisons of this installation.

THE COOPER HEWITT MERCURY-VAPOR LAMP.—This lamp has found extended use since its introduction in 1903 in places where a very low operating cost, and the tubular form, with low intrinsic brilliancy and good diffusion, are of greater importance than having a natural color value of illumination. As the lamp has become rather more simplified than when first introduced, and as it is at present the most efficient commercial light source, it will be described, and its use briefly outlined.

The complete lamp for direct current comprises the tube and holder, and a small set of inductance and resistance coils connected in series with the tube. The tube is of a special glass, carrying an iron electrode at the upper or positive end, and a mercury electrode at the negative or bulb end, connected with the outside by platinum wires sealed in the glass. The tubes are made in lengths of 21 and 45 ins., of a diameter of 1 in. for candle powers of 300 and 700, respectively, for the general groups of voltages about 110 and 220, respectively. The tube can be adopted for any commercial voltage, though the candle power changes slightly for different voltages. Only a small quantity of mercury is contained in the bulb at the negative end. The tube is exhausted and sealed similar to Crookes vacuum tubes.

The tube is supported by two clamps, fastened to a "lamp rod," which is parallel to the tube. The lamp rod is pivoted to the main stem, which is screwed into the ceiling crowfoot. The auxiliary coils, etc., are also supported by the stem and covered by a metal canopy. In some cases a reflector is fastened to the lamp rod. All this is shown by Figs. 13 and 14.

The mercury tube, considered alone, has a peculiar characteristic whereby it experiences momentary increases of resistance of sufficient magnitude to break the continuity of the arc. This seems to disappear with a current of over four amperes, and with smaller currents when the negative electrode becomes hot. With the 3.5-ampere lamp, the commercial type, it has been found necessary to introduce inductance in series with the tube so that the magnetic energy stored opposes and overcomes the tendency to reduce the current. This effect of increasing resistance tends to become cumulative, as a certain-sized inductance has been found to keep the vapor stream continuous for a few seconds, while a larger one would be necessary to maintain it for a few minutes or an hour, and a still larger one for absolute continuity.

Roughly speaking, an increase of induction in the circuit of ten times lengthens continuity of action about 1,800 times.

Cooper Hewitt lamps were formerly started in some types, by a high-tension apparatus, which has been discarded, though perhaps only temporarily. While the high voltage momentarily required was confined to the lamp and did not affect the supply voltage, yet a higher degree of insulation, and costly workmanship was demanded in the lamp itself, for this type. The whole lamp was, therefore, more expensive and less simple than the present commercial forms. In the types now for sale the tube is tilted and the mercury in the tube poured, in a small stream, between the two electrodes. A short circuit is prevented by an auxiliary resistance. When this stream is broken by returning the tube to normal the arc is started and the lamp put into operation. This tilting is accomplished by a chain attached to the upper end of the lamp rod, or by a solenoid on the stem at the pivot joint of the lamp rod.

It is impossible to work the simple direct-current tube on alternating currents on account of the phenomenon noted under alternating-current arcs, mercury being one of those electrode-materials with which the voltage consumed in an arc is much less than the sparking voltage at the temperature of the arc.

The tube for the alternating-current lamp is similar to the direct-current type, except that the upper end carries two positive electrodes and a small starting electrode (connected through resistance to one positive).

The starting is accomplished by tilting the tube by a chain. The mercury flows out of the bulb as in the direct-current type, and strikes the starting electrode, but skips the positive electrodes, which are in pockets on the upper half of the tube. On account of the irregular flow of the mercury about the starting electrode it makes and breaks the circuit, starting an arc. If the arc be started at such a point of the alternation of current that the mercury column is the negative electrode, then the arc will continue between the merucry and (alternately) the starting electrode and that positive to which the starting electrode is not connected. On account of the resistance connected between the temporarily inactive positive and the starting electrode the arc will not be maintained on the starter, but on both positive terminals alternately. If there were no resistance between the starting electrode and that positive electrode to which it is connected, supposing the arc to have just been started, and the tube still tilted, should the mercury touch the starting electrode again the arc would fail, as a metallic path would be placed ir parallel with it.

As the candle power of the mercury arc varies considerably with variations of voltage, some auxiliary regulating apparatus needs to be included in the circuit. A "ballast" resistance has been provided, quite similar to that used with the Nernst lamp. An iron wire is wound on a por-

TABLE I.—POUGHKEEPSIE LIGHT, HEAT & POWER CO. STREET-ARC SYSTEM.

Operating Data.

Number of circuits	6.
Number of street lamps	325.
Number of switchboard panels	7.
Voltage of constant potential.	
Steam system	4 306-HP. water tube and 2 150-HP. horizontal tube boilers. 2 reciprocating engines. 1 Curtis turbine.
Coal burned	Soft coal, at $3.30 per ton.
Chimney draft.	
Watts per lamp	310.
Watts per lamp, old system.	480.
Cost renewals, trimming, repairs, etc.	$4.89 per lamp, year.
Contract price paid by city.	$84 per lamp, year.

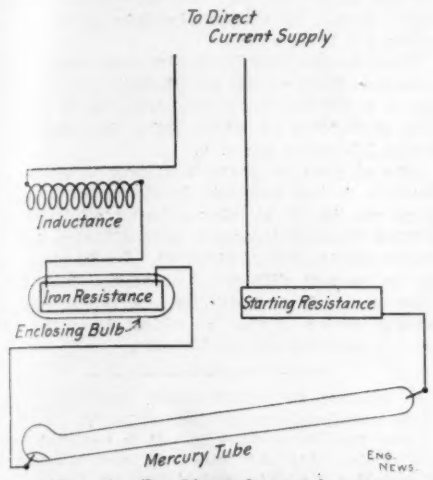


Fig. 11. For Direct Current Lamps.

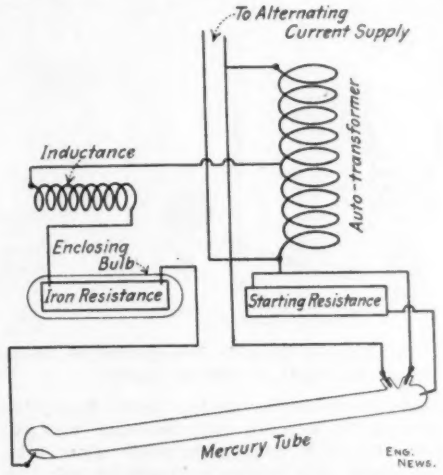


Fig. 12. For Alternating Current Lamps.

FIGS. 11 AND 12. DIAGRAMS SHOWING ARRANGEMENT OF PARTS OF MERCURY VAPOR LAMPS.

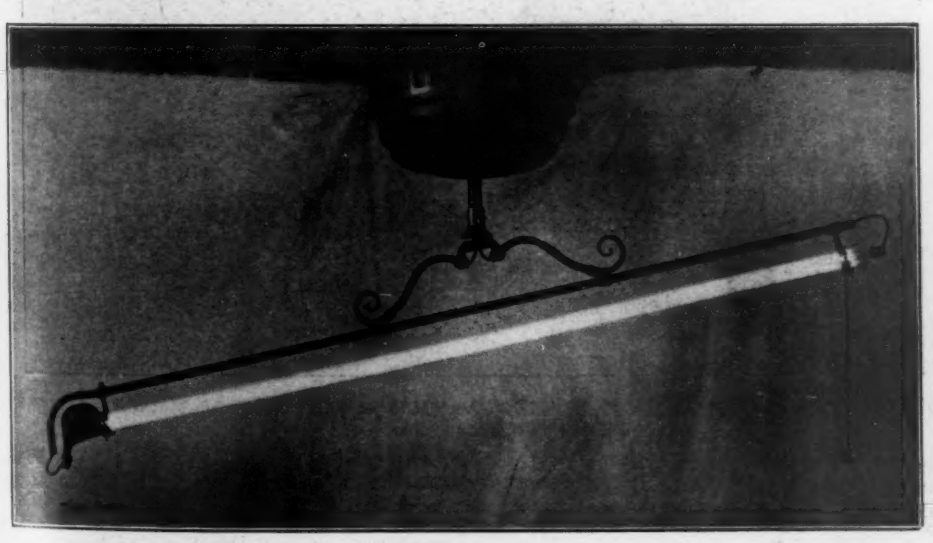


Fig. 13. Direct Current Form.

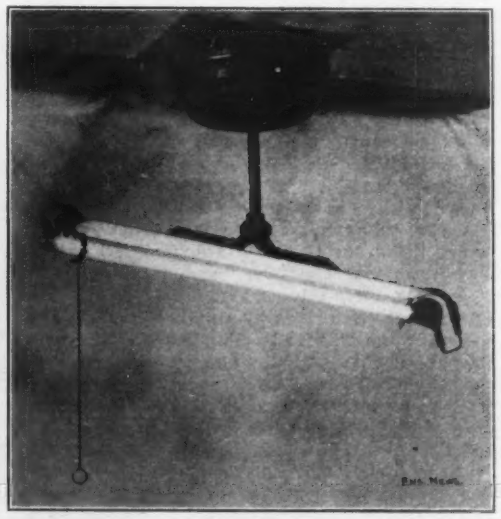


Fig. 14. Alternating Current Form.

FIGS. 13 AND 14. THE COOPER HEWITT MERCURY ARC LAMPS.

celain pencil and the whole sealed in a glass tube through which the terminals pass. Iron has the property of greatly increasing its resistance by passage of relatively small current. At 500° C., the working temperature of the "ballast," this effect is enormously accentuated. The coil is placed in series with the arc, and is so designed that a slight decrease in the current causes such a decrease in the voltage drop across the terminals of the coil that the remaining portion of the voltage impressed on the lamp remains more nearly constant.

The mercury lamp is the invention of Mr. Peter Cooper Hewitt, of New York City, but the present commercial forms were largely developed by the Cooper Hewitt Electric Co., 220 West 29th St., New York City, one of the Westinghouse interests.

The mercury-arc lamp has found its widest application in various industrial and commercial plants. On account of the comparatively large candle powers and peculiar colors it is limited to such places.

Those who have not worked under the light are the strongest objectors to its green color. It certainly has a strangeness at first; color values are upset; and persons take on a ghastly pallor. However, many manufacturers and shop operators state that workmen, clerks, and draftsmen, alike, soon become used to the absence of red rays and that the eyes apparently are less fatigued by the same length of time in close application to fine work than with those illuminants yielding more red rays.

The current consumption for a given amount of light is particularly economical with the use of the mercury lamps, being claimed to be about half that of open arcs, a third of the enclosed-arc figure, and a sixth of the common incandescent service. While the first cost is high, yet it may, under many conditions, be lower than the installation cost per candle power for incandescent service. This item of installation cost has varied from one-half to twice that of the other forms of electric lighting. However, the makers claim to be able in almost every case to guarantee that the reduced operating cost will be such as to pay the entire cost of installation on equipments of considerable size.

The life of the tubes is guaranteed for 2,000 hrs., and averages much above that, perhaps, about 5,000 hrs. Individual cases have run to 7,500 hrs. The general appearance of the alternating and direct-current lamps is given in Figs. 13 and 14.

THE MOORE VACUUM TUBE.—Mr. D. McFarlane Moore began his work on commercializing Geissler tubes about twelve years ago. In the various stages of development the system has had different lengths, sizes and shapes of vacuum tubes and numerous devices for the production of the necessary high potential to make the tubes luminous. As these have been noted in various scientific journals and papers and as they are not in use, mention will be made only of the form actually being installed for practical lighting.

In its present form the vacuum tube consists of a 1¾-in. glass tube of any desired length supported near the ceiling by suitable brackets and encircling the area to be illuminated. This continuous tube is made in place from 6 or 8-ft. lengths, joined with blow-pipes by methods made familiar by makers of physical apparatus. The ends of this long tube are brought to a steel box about 2-ft. square. Large carbon electrodes are inside each end of the tube, connected to the outside contacts by platinum sealed in the glass. The completed tube is exhausted in position by a portable mechanical vacuum pump to a pressure claimed to be about 1-40,000 of an atmosphere.

The necessary high tension current is obtained from a simple transformer, located in the steel box mentioned above.

It was early shown that, with such tubes, the rarefaction steadily increased, increasing the resistance in an obscure manner until it became too high for the working voltage. Consequently the light of the tube soon went out. This difficulty is at present overcome by a most ingenious regulating valve. A piece of ⅞-in. glass tubing is supported vertically, with its bottom contracted into a ⅝-in. glass tube, which extends to the main lighting tube. At the point of contraction a ¼-in. carbon plug is cemented in. Its porosity is such as to allow gases easily to percolate through, but not sufficient to allow the mercury which

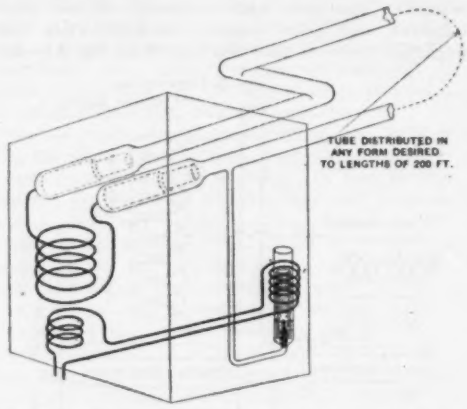


Fig. 15. Diagram Showing Arrangement of Essential Parts of "Moore Light."

normally completely covers it to pass. Partly immersed in the mercury and concentric with the carbon plug is a smaller movable glass tube, whose upper part carries a bundle of soft iron wires, which form the core of a solenoid in series with the primary of the transformer. All these parts are shown in the diagram, Fig. 15. There is a critical point of vacuum at which the conductivity is a maximum, and the tube normally works a little below this. As the vacuum becomes higher the conductivity increases and a greater current flows through the solenoid. This lifts the displacer, lowers the mercury level and exposes the carbon tip. Immediately a minute amount of gas passes into the vacuum tube, until the vacuum falls to normal and equilibrium is established again. This action is repeated about once a minute during the use of the tube. This feature of the Moore apparatus is also shown in Fig. 15.

When the regulating valve is arranged to admit air, the light given by the tube is rose-colored. If nitrogen is used the light is yellow, and when carbon dioxide is admitted a close imitation of daylight color values is obtained. It should be stated that the tube giving "white" light is not as efficient in light production as when air is admitted.

Tests by the New York Electrical Testing Laboratories have shown an efficiency of 0.65 watts per c. p. for the rose-colored tubes; with those for the production of white light the efficiency is about 1.5 watts per c. p.

The advantages of the light may be briefly presented: A low intrinsic brilliancy of about 12 c. p. per lin. ft. of tube; a better efficiency than carbon filament lamps; a good diffusion, but not entire elimination of shadows. Its disadvantages lie in present difficulties of repair, high initial cost and lack of flexibility. A typical installation is shown in Fig. 16, which shows the lobby of the Madison Square Theater.

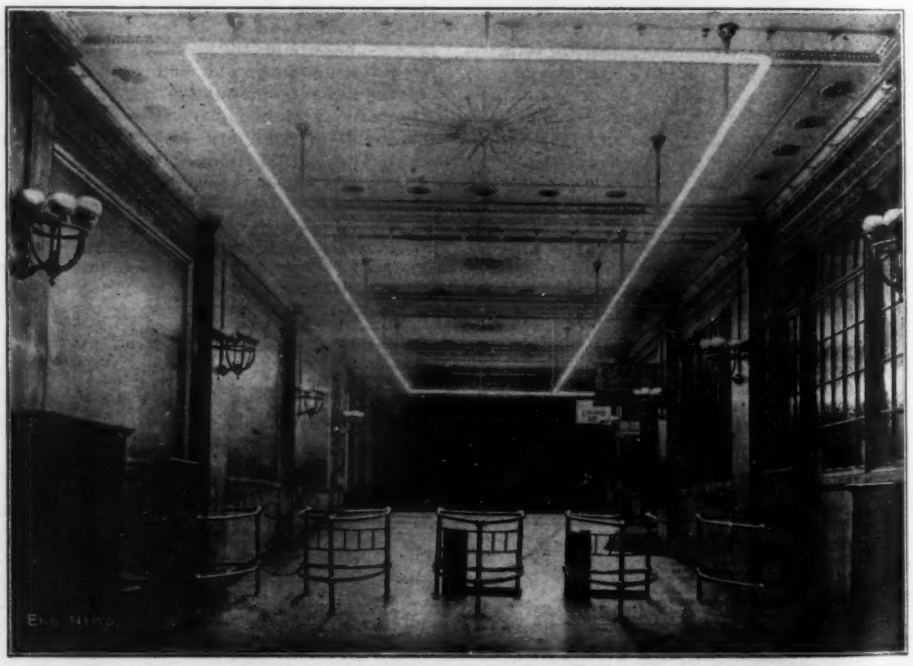


FIG. 16. TYPICAL INSTALLATION OF MOORE VACUUM TUBE, LOBBY OF MADISON SQUARE THEATER, NEW YORK CITY.

A SYSTEM OF PERMANENT, DUSTLESS HIGHways is projected for Los Angeles County, Cal., by the County Highway Commission. It is estimated by the Commission that the work will cost approximately $3,000,000, and advices received from Mr. Ray L. Chesebro, Secretary of the Commission, indicate that it is ambitious to build a system of roads that will attract national attention. Mr. Arthur E. Loder is Chief Engineer of the Commission.

BRITISH GAS STATISTICS for 1905 are briefly summarized by our contemporary, "The Progressive Age," in its issue of July 15. A portion of the summary is reproduced here in the accompanying table, based on the annual publication known as "Field's Analysis of British Gas Undertakings:"

Per 1,000 cu. ft. of gas sold in 1906.	Private. London.	Private. London suburban.	Municipal. Provincial.	Municipal. Scottish.	Private. Provincial.	Private. Dublin.
	(3)*	(12)	(9)	(2)	(9)	(1)
Capital employed	$2.71	$2.61	$2.63	$2.45	$2.45	$4.00
Working expenses	0.319	0.357	0.259	0.243	0.257	0.298
Average price	0.598	0.640	0.530	0.530	0.464	0.796
Cost of coal	0.267	0.316	0.229	0.276	0.240	0.327
Gross profit	0.215	0.182	0.185	0.178	0.164	0.302
Net profit	0.185	0.152	0.096	0.035	0.145	0.258
Capital charges	0.210	0.175	0.068	0.100	0.154	0.299
Residuals per long ton coal	2.08	2.06	1.64	1.42	1.73	1.97
Increase gas sold, per cent	2.26	5.97	3.23	1.97	3.05	—1.02
Unaccounted for, per cent., make	4.79	5.68	5.14	9.04	6.44	10.04

*Numbers in parenthesis in the column heads indicate the number of companies of each class.

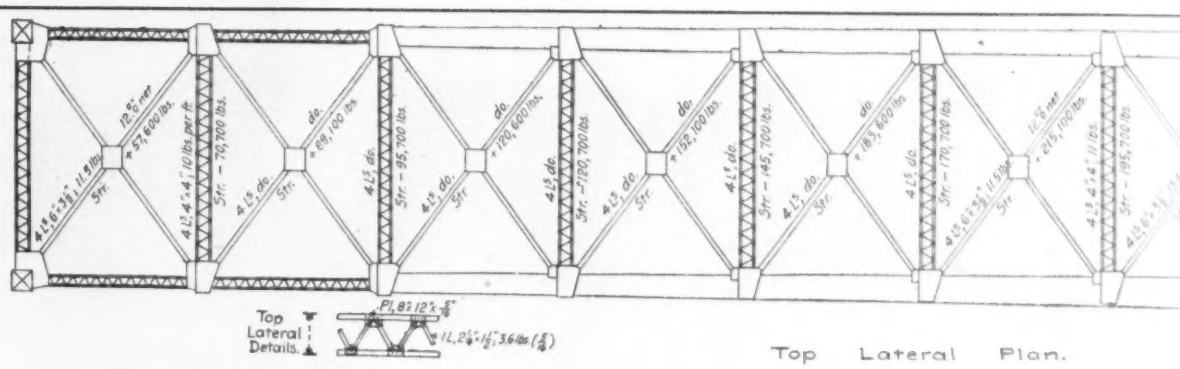
LIVE LOADS.

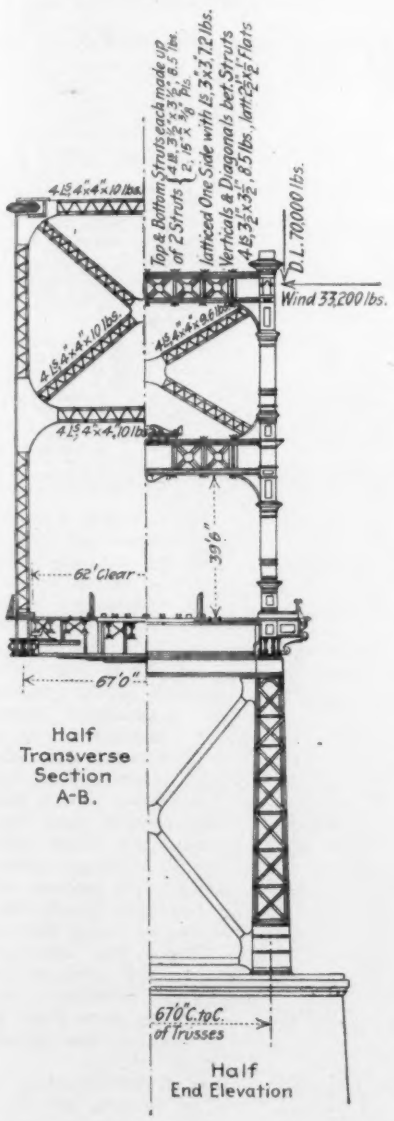
I. **TRUSSES IN GENERAL:**

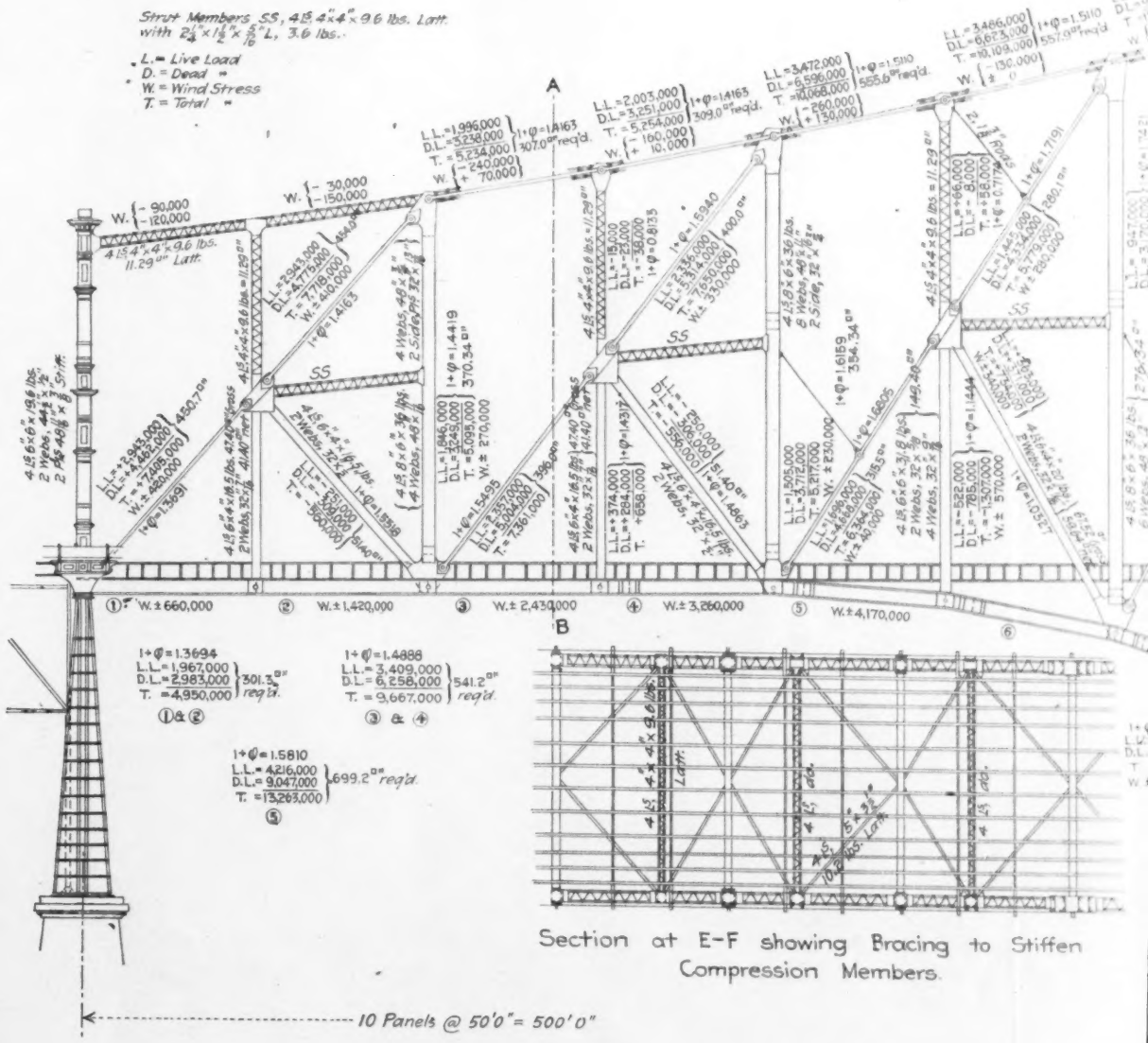
(a) On each steam railway track, 3,000 lbs. per lin. ft. for unlimited length; or (b) on each steam railway track, two Class E-33 locomotives followed by a train of 3,300 lbs. per lin. ft.; total length of train, 900 ft.; or (c) on each steam railway track, one Class E-40 locomotive followed by a train of 4,000 lbs. per lin. ft.; total length of train, 550 ft. No loading on electric railway tracks, roadways or sidewalks.

II. **HANGERS, SUB-DIAGONALS AND FLOOR SYSTEM:**

(a) On each steam railway track, two E-40 locomotives followed by a train of 4,000 lbs. per lin. ft., and (b) on each electric railway track, 56,000 lbs. on two axles, 10 ft. apart, with 20 ft. to leading axle of car following, and (c) on each roadway, 24,000 lbs. on two axles 10 ft. apart.




Top & Bottom Struts each made up of 2 Struts
Lattced One Side with
Verticals & Diagonals bet. Struts
D.L. 70000 lbs.
Wind 33,200 lbs.
62'Clear
67'0"
Half Transverse Section A-B.
67'0" C. to C. of Trusses
Half End Elevation

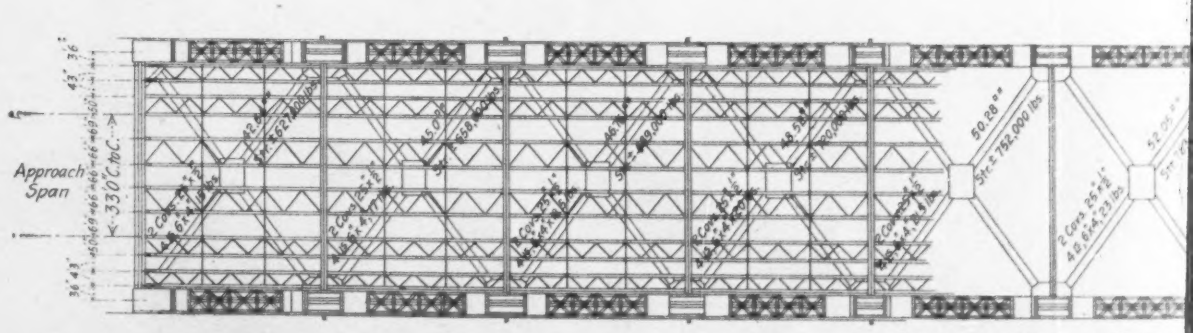


DEAD LOAD.

Lumber	2,500 lbs. per lin. ft.
Floor	3,700 lbs. per lin. ft.
Total from floorbeams	6,200 lbs. per lin. ft.
Trusses and bracing:	
Ave. on susp. span	7,800 lbs. per lin. ft.
Ave. on cant. arm	18,510 lbs. per lin. ft.
Ave on anchor arm	17,880 lbs. per lin. ft.

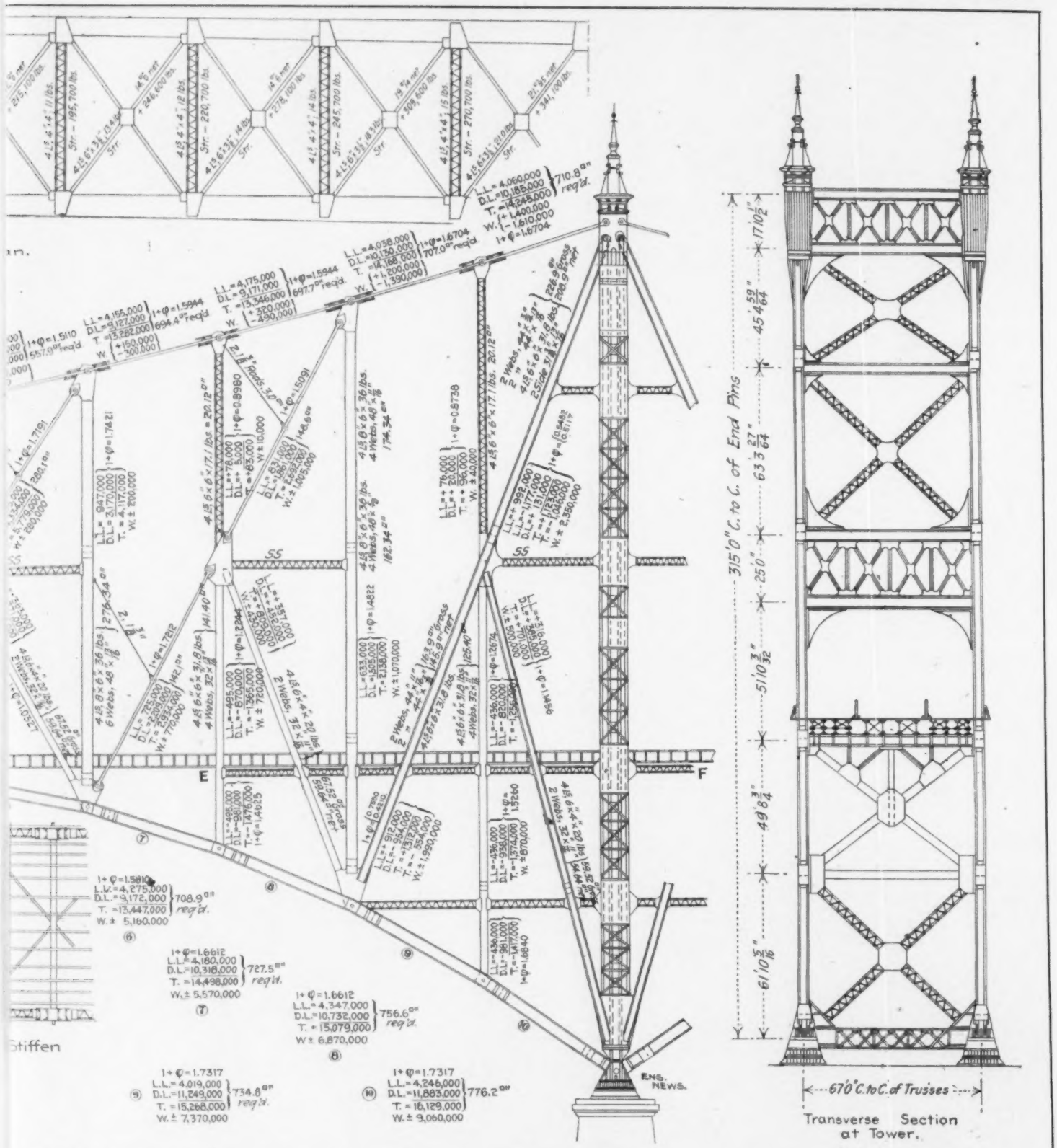
WIND LOAD.

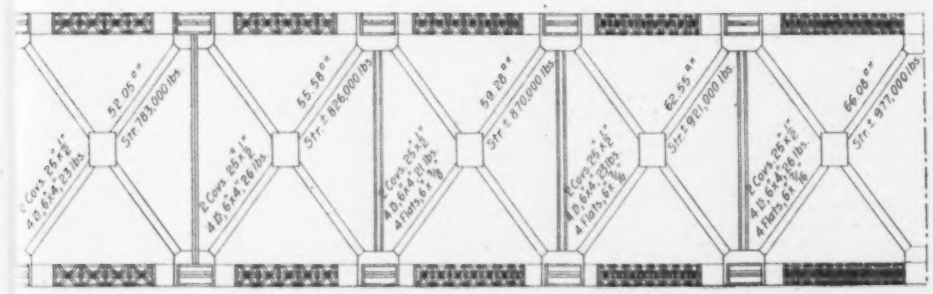
Top laterals	500 lbs.
Bottom laterals	1,000 lbs.



STRESS DIAGRAM OF ONE 500-FT. ANCHOR ARM FOR ST. LAW

The Phoenix Bridge Co., Phoenixville, P





Plan.

Material: Medium steel.

Specifications: The Quebec Bridge Company's, as recommended by Theodore Cooper, C. E.

Figures show stresses in pounds for one truss.

ST. LAWRENCE RIVER BRIDGE, QUEBEC, CANADA.

enixville, Pa., Builders.

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We deem it proper in this prominent place to acknowledge the courtesies and assistance which have been given to the editors of Engineering News, in connection with the preparation of our articles on the Quebec Bridge disaster in this and the preceding issue, by all those most directly concerned. The officers of the Phoenix Bridge Co. and of the Quebec Bridge Co. and the members of the Canadian Government Investigating Commission have placed every facility at our disposal. All have freely recognized that the disaster was a matter of gravest moment to the whole engineering profession, and that it was entitled to all the information that the most diligent search could uncover. While the public has been necessarily excluded from close inspection of the wreck to prevent possible accident from falling pieces, engineers have been freely admitted; and the opportunity is one which should be improved by every bridge engineer who can possibly arrange to visit Quebec this fall. The most graphic description and the completest resources of photography cannot teach such an object lesson as actual examination and study of the wreck.

High praise is due to the Dominion Government for its prompt action in appointing a commission of engineers to investigate the disaster and report upon the technical questions involved. Canada is fortunate in having in the responsible position of Deputy Minister of Railways and Canals, Mr. M. J. Butler, M. Am. Soc. C. E. It is doubtless due to his good judgment and intimate knowledge of the profession in Canada that the Commission was made up of engineers well qualified to sift the whole matter to the bottom and settle the many knotty questions involved. Doubtless this work will require weeks and perhaps months. The engineering profession will follow with the greatest interest the work of this Commission and will await its conclusions with strong confidence in their soundness and reliability.

The hydro-electric power plant which is now in process of construction at McCall Ferry on the Susquehanna River, and which we describe in this issue, takes a place near the head of the increasing number of such developments which have been constructed in the last decade. At first glance the most noteworthy feature of the undertaking would seem to be its immense size. Unfortunately mere magnitude of quantities is often regarded as sufficient to emphasize the importance of an engineering work without reference to the quality of the construction or the efficiency of the design. But in this plant the huge quantities employed are notable principally on account of the facility with which they are handled; the difficulties are important because of the ease with which they are overcome.

The whole plant is essentially a concrete structure. In fact, the plan as worked out is largely dependent upon the use of concrete; no other material would have made possible the special methods of construction employed. The alternate dam sections, the molded draft tubes and intake pipes, the construction bridge, and, finally, the method of filling the dam behind the stop-log curtains are all due to the peculiar properties of concrete, which allow a rapid placing of a great quantity of material in a variety of shapes. The efficient use of this concrete is itself dependent upon the admirable layout of the erecting plant, which permits of the manufacture and disposal of large amounts of concrete in a short time.

Special attention is called to the method of constructing the main spillway dam in alternate sections, which are afterward to be closed by means of a novel portable stop-log curtain. This method, as far as we know, is entirely new in this exact form, and in the extraordinary conditions of flow here present, seems to solve the problem of construction as no other method could. It is to be regretted that up to the present time these stop-curtains have not been tested under anything but the lowest stages of water. Their successful operation under large heads will add an efficient tool to the machinery of dam building.

The method of conducting the work by day labor under the direction of the engineering force in the employ of the company has rarely been attempted on so large a scale. With the right sort of management and with efficient men in charge of the work this should ensure the highest class of construction to be procured. The fault to be found in such a system lies in the probable high cost price. An engineer in charge of so large a work is not so impressed with the need for financial economy as is the contractor, to whom the successful completion of the work means the difference between a small fortune and ruin. No matter how conscientious the engineer may be he is extremely liable to run his costs to a higher figure than the probable lowest bidders. But it should be remembered that the financial success of the operating electric plant largely depends upon its maintenance charges, and these charges decrease with the solidity and increased efficiency of the constructed plant. A large plant built by a constructing engineer working with day labor, not hampered by any financial bugbear, but striving faithfully and with his best judgment to get the best present and future construction, should, on account of lower maintenance charges, finally bring in a higher interest on the investment than a plant of lower first cost, built by a contractor endeavoring to finish the work just within specifications, and at low enough first cost to guarantee a good profit to himself. The first cost of the McCall Ferry Plant will undoubtedly be high. The equipment is of the very best. No money has been spared where it seemed necessary to provide machinery or plant to successfully prosecute the work. As a result, however, the very best class of work has been procured, and difficulties which appeared at the outset to be of great moment have been passed over with little or no trouble. The mishaps incidental to a cheap erection plant have been entirely absent.

The successful prosecution of so large a work as this involves a painstaking selection and watchful care of three things: the materials, the plant, and the men. The materials and the plant are prime factors in every engineering work and rules for their selection are the main part of any engineer's experience. The study of the men increases in importance with the size of the work. The problem of housing and maintaining a corps of a thousand or more workmen so as to provide fair comfort for the majority is one that even the greatest engineers are very infrequently called upon to solve, but is, nevertheless, as worthy of their close consideration as the designs of the plant with which to build the structure, or the study of the nature of the materials which go to make it up. The camp at McCall Ferry is a model of its kind. Its provisions for water, sewerage, lighting and telephoning make it seem more than a temporary affair. The sanitary inspection and hospital equipment are far better than in the average town of the same number of inhabitants. Purely as an economic consideration it is probable that the satisfactory housing of the great number of men here employed has increased the value of their working output far in advance of the cost of the camp.

In another part of this issue and in an earlier issue there are outlined the forms into which certain light-sources have been developed. In connection with these studies it is interesting to take notice of the commercial prototypes of these forms and the lines along which their evolution may be expected.

The present varied forms of arc lamps may be said to have sprung from the old carbon open arc, conspicuous by the great intensity of light emitted, by irregularity of action and by comparatively clumsy appearance. While many old open arcs are still in evidence yet the type has been practically superseded by the enclosed form, which has a higher degree of diffusion, lessened intensity, greater steadiness and requires less attention. When the replacement of the old open-arc was evident, it seemed that the height of its development had been attained. However, after occupying a minor place for several years, the open type now appearing with simplified mechanism and electrodes of somewhat different material, promises to supplant its own temporary successor. "Flaming" and "metallic-arc" lamps are by no means completely or satisfactorily developed as yet. For instance, the present flaming arcs are best adapted to burning two in series on a 110-volt supply or four in series on 220 volts or thereabouts. They are not adapted for burning 25 or 50 on a series circuit, though such a form is promised by some designers. The necessity of trimming every 10 to 17 hrs. seems to be an inherent trouble. The metallic-arc lamps are not yet practical for alternating-current circuits, and considerable trouble and loss of efficiency result from the necessity of transforming the prevalent alternating current to uni-directional. It may be shown that with the cost of supplying alternating current at 1.5 to 2.0 cts. per KW.-hr. the saving of the metallic-arc street lighting system, with mercury rectifiers, over the enclosed-arc system with constant-current transformers only is from $4.50 to $8 per lamp per year. If these metallic-arc lamps can be developed to operate satisfactorily in series on alternating current the figures quoted may be expected to increase to $5.50 and $12, respectively.

In the early forms of the Cooper-Hewitt mercury-arc lamps, localized high potential was used to start the arc. In the forms now on the market this starting is done mechanically by bringing the electrodes into electrical contact and then breaking the contact. To do this the tube is tilted from its normal position until a small stream of mercury runs between the electrodes. In some places where these lamps are used this mechanical starting by more or less careless employees is not altogether satisfactory. In other words, the lamp is not at all fool-proof. The type of lamp designed for alternating current has not proved as desirable as the one for direct current. The peculiar green color seems unalterable under conditions which at present allow practical operation. When the mercury vapor lamp is more available for alternating currents and without the necessity of starting the arc by a mechanical disturbance of the tube, its widespread adoption seems very probable in

all locations where the distorted color values are of minor influence.

One of the remarkable developments in electric lighting is the achievement of Mr. D. McFarlane Moore—making a practical illuminant from the old Geissler tube, so long a spectacular feature of static electrical demonstrations. It is especially praiseworthy in being the result of many years of persistent and oftentimes disappointing experimenting, adhered to in spite of constant predictions that the quest for "the light of the firefly" was but that of a "will o' the wisp." In the past years of development the Moore tubes have assumed various forms and nearly, if not quite, all the means of producing the necessary high-tension current have been used. In its present form it is surprisingly simple—a long vacuum tube with electrodes, a vacuum-regulating valve and a small static transformer. The Moore tube as an illuminant cannot be called perfect; its stroboscopic effects are pronounced; its most efficient form gives a rose-colored light, and above all it lacks flexibility. However, the obstacles still to be overcome do not seem as great as those already surmounted, and still further advance may reasonably be expected.

When one contrasts the old Edison lamps with their carbonized bamboo filaments and the tungsten lamps of to-day the great advance is apparent. The power consumption for a given amount of light has been reduced to less than one-fourth of its early value. Even in the new filament lamps the limit of development does not seem to be approached and there are several lines of possible advance. For instance, all the new filaments are not available in small candle power units for commercial voltages; the tungsten filament is exceedingly fragile; the tantalum lamp does not have a long life on alternating current. This discussion of possibilities is not made in criticism of what has been accomplished; the usefulness of present forms is not forgotten.

Beneficial as has been the development of better and more efficient electric lamps, it has nevertheless been accompanied by a persistence, on the part of manufacturers, in rating their products by power required rather than by light given.

The newer incandescent lamps are designated "40-watt units" or "100-watt units," or whatever the consumption may be, instead of by candle power or by using any units which directly express the luminous qualities. In street lighting 310, 450 or 500-watt lamps are dealt with, and too little is said about actual candle powers, distributions or illuminating values. While it is true with the new lamps that the actual production of light is more efficient than before, yet it is more difficult to get an idea of the actual amount of light expected for a given expenditure of energy. The consumers, judging superficially, feel that the lamp makers and central-station managers are forcing them to maintain the present amount of energy consumption when they wish to maintain the present amount of light. It may be that in many cases more light for the same energy is better than the same amount of light for less energy, but that cannot be a valid excuse for rating lamps so that the illuminating value is not directly indicated. These conditions seem anomalous; the manufacturer applying all available talent to produce better light-sources, yet rating the lamps so that their merits are less evident.

Superintendents and engineers in charge of shop maintenance are usually careful to provide the most economical light-sources in the most approved and carefully planned manner. However, the bulbs and tubes are allowed to collect dust and grime; proper attention is not given to renewals; walls and ceilings are not whitened where such are permissible. Failure to keep these external conditions up to a certain standard surprisingly reduces the effective illumination. An engineer, with opportunities for wide observation, has stated that efficient illumination depends to the extent of 40% on providing the best lamps of the highest efficiencies and 60% on clean lamps, proper renewals, whitened walls and regularly cleaned interior surroundings. The duties of those responsible for lighting a factory do not end with the proper installation of good apparatus.

THE QUEBEC BRIDGE FAILURE: OUR DEFICIENT KNOWLEDGE OF THE STRENGTH OF LARGE COLUMNS.

In our last week's issue we located the point of initial failure in the Quebec bridge collapse within narrow limits. Such information as has been gathered since that time tends to confirm all the conclusions then expressed and points with steadily increasing certainty to the lower chord member 9A in the left truss as the point of initial failure in the structure.

We recorded last week how this member was found to be bowed slightly out of line three days before the disaster and the steps taken by the engineers on the spot to secure as quickly as possible advice from their superiors as to what measures, if any, were demanded.

Looking at that occurrence in the light of what has since happened, it is plain that the condition of this chord member was a danger signal of gravest significance, and that its discovery ought to have been followed instantly by suspension of all work on erection and summoning of the engineers at the head of the work to the spot. But it is always easy to be wise after the event. The engineers on the work had such absolute confidence in the integrity of the structure and the excellence of its design and construction, that it must have seemed to them incredible that this huge chord could be in any serious condition when the load upon it was far below that which it was designed to safely carry.

There was, indeed, difference of opinion. Mr. Birks, the Resident Engineer on the work, who met death in the disaster, believed, we are told, that this chord member had always had that bend. Mr. McLure and Mr. Kinloch, the inspectors on the site, believed the bend was of recent occurrence, and this meant of course that the huge column was giving premonitory signals of distress. Mr. Milliken, the Superintendent of Erection, had left Quebec the day before the bend in chord A9L was discovered. In his absence, as far as we are now informed, Mr. Birks was the only engineer on the ground with authority to order suspension of work, and his opinion, as we have seen, was that the bend was not of important significance.

Mr. Hoare, Chief Engineer of the Quebec Bridge Co., was summoned at once, and on Wednesday morning the whole engineering staff again discussed the matter and examined the member. That all were worried by it—with the possible exception of Birks—is evident; yet Mr. Hoare did not order summary action in stopping erection work. Perhaps it was felt that the dismantling and removal of the large 1,000-ton traveler, then in progress, was taking weight off the structure as fast as the erection of the suspended span was adding it.

All were agreed, doubtless, that the bridge company and Mr. Cooper, the Consulting Engineer, should be notified at once. The telegraph was not to be relied on by reason of the strike. The long distance telephone was not used, whether because of difficulty in securing connection or what other cause is not yet known. The action decided upon was to send Mr. McLure by the first train, to New York, to report to Mr. Cooper and thence to Phoenixville. He arrived at New York on Thursday morning, and found Mr. Cooper, who appears to have appreciated the serious significance of the news. Had his telegram to Phoenixville, advising stoppage of work, been delivered with promptness, it is barely possible that action might have been taken to clear the bridge of workmen before the collapse, which occurred that very afternoon.

Yet we say again, it must have seemed to all concerned, so incredible that this huge column could actually be in an overloaded condition, that there is nothing strange in the delay which occurred.

It is a matter of some interest indeed to speculate what could have been done had there been time for the builders to act before the collapse occurred. Of course the work of erection could have been suspended and the working force removed from danger. It would then have been in order to determine the cause of the bend and the actual condition of this and other compression members; but how this huge chord member could have been straightened, while carrying its enormous load, or even rendered secure against further deflection and collapse is a problem which would have been without precedent in engineering.

We recounted last week the successive steps, in analytical study of the wreck and of the circumstances in connection with it, which point to lower chord member A9L as the most probable place of initial failure. Theories locating the point of failure elsewhere have been suggested to us by correspondents and others during the past week; but every one of them thus far proposed is proved incorrect by known facts in connection with the failure.

But a question of far more importance to the engineer than the question which member caused the initial failure is the question, WHY DID THE MEMBER FAIL? If we accept chord A9L as the point of initial failure, what caused this huge column—intended by its designers to safely carry a load at least a third greater than it bore at the time of the accident—first to buckle out of line, to a sufficient degree to be discovered by a watchful inspector and later, as the stress on it was increased by the building out of the suspended span, to give way entirely?

There are two and only two possible answers to this question. The one is that this member had some inherent weakness, due to defects in manufacture, to accidents in handling or transportation, and possibly in combination with these to delay in completing the field riveting of its connections.

The other answer is that this member was typical of all the members of its class, and that, while it was the first to fail, all members of its class were also loaded to the point of serious danger.

If the first answer is correct, then the Quebec bridge collapse was due to a single fault in construction, which unusually careful inspection failed to detect. If the second answer is the true one, however, then there was a radical fault in the design of all these huge struts; and it is fortunate that the accident occurred before the construction had proceeded farther. Sad as is this catastrophe in all its phases, it would have been far worse had the bridge been finally completed and put into use, and had then crashed down two hundred feet into the St. Lawrence, perhaps with a whole train-load of passengers.

Of these two answers all the facts and circumstances now available appear to indicate the second to be the answer nearest the truth.

We say this while admitting that lower chord A9L was probably "a weak sister." It appears to have suffered accidents of one sort or another, in the shop, in transportation, and in handling at the bridge site. When placed in the work, however, it is hardly possible to doubt that it had been straightened and was believed by every one concerned to be perfectly safe and reliable. Certainly the constructors of the bridge believed this, for the enormous interests they had at stake were too vast to be jeopardized by running risk anywhere. All through the work they have exercised unprecedented vigilance, and went to hitherto unheard-of expense to safeguard every possible point. They would have made twenty new members like this, rather than put a single one into the work which they dreamed was untrustworthy.

Notwithstanding the fact that Mr. Birks, the Resident Engineer, thought when the bent condition of the chord was discovered that the bend was of long standing, it is not conceivable that the chord can have had such a bend when it was put in place in the bridge. A deflection of 2 ins. in a 57-ft. column would have been

perceptible to every one who handled it. No one concerned with the work would have approved the placing of such a member in the structure, and least of all a member designed to carry a load so enormous.

The only single fact indicating that any one had the least suspicion of lower-chord member A9L is that the bend in it was discovered at all by Mr. Kinloch, the Government inspector, just before the accident. Unless the past history of this member had put him on guard, he had no more reason to watch for signs of bending in chord nine than in any other of the many struts in the bridge. This again, however, is added evidence that this member was straight when originally placed; and in fact had been straightened from a previous bent condition.

Let us admit, we say again, that 9A had at some time been maltreated, so as to be slightly out of line. Is this a sufficient reason why it should first deflect and then buckle in the way it did? Are our bridge struts such frail affairs that a little carelessness in shipping and handling may render them inherently weak and unreliable? Surely this is not or at least ought not to be the case. No careful engineer, of course, would incorporate in a bridge structure members which were seriously out of true; but if lower-chord member A9L had had the stiffness it should have had to carry its load, it would never have gone out of line and collapsed as it did, notwithstanding its past history.

And now let us proceed a step farther. Study of the wreck at the bridge site points strongly to the conclusion that when lower-chord member 9A in the left truss was at the point of failure, *some compression member in the opposite truss was in almost the same condition.*

To show this, let us for a moment assume the contrary case and suppose that 9A was the only weak member in the bridge and that all others had the margin of safety for which they were designed. If this had been true, then the left-hand truss would have failed appreciably before the right-hand. Destruction of the cross-bracing would of course quickly wreck the left trus also; but almost certainly it would have held together several seconds longer than the left-hand truss and would then have gone down on top of the other. At least, the wreck would bear evidence of such a sequence in failure of the two trusses.

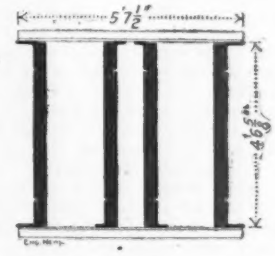
What the wreck actually indicates, however, is that the failure of the two trusses was probably nearly simultaneous. If anything, the wreckage of the anchor-arm lies to the right of the center line of the bridge; its center of gravity in falling appears to have gone eastward, perhaps 8 to 10 ft. The bottom chord of the left-hand truss is plainly visible nearly the whole length of the anchor-arm. The bottom chord of the right-hand truss is buried under wrecked web members nearly all the way.

If chord member 9A on the left failed first, then almost simultaneously a member in the opposite truss, perhaps the chord member directly opposite, went, too. It went because it was also overloaded, and the stresses produced by the falling truss opposite almost instantly buckled it like its mate on the other side.

Here we have at least two compression members designed for a compression stress of 24,000 lbs. per sq. in. and failing at a load of some 16,000 lbs., not more than half the elastic limit of the metal in tension. Why did these members fail? It was not weakness at the ends. The construction of these members at the joints was worked out with greatest care to properly distribute the stress and the workmanship was of the highest excellence. It was not faulty material. The steel of this bridge has been subjected to a more terrible ordeal than any testing laboratory ever devised. It has been torn, twisted, bent and crushed in every possible way; but its fractures indicate it to be throughout just the ductile, homogeneous metal which the designers aimed to secure. Further, even brittle material would not explain a failure under a compression by static load. We may admit perhaps a possibility that incomplete field riveting may have contributed to weaken the members; but from any evidence thus far uncovered, it does not seem to have been in any degree the chief cause.

All other causes of failure being found untenable, one is forced to the conclusion that these members failed from lack of stiffness. The more one studies this huge scrap-heap on the south shore of the St. Lawrence, the more one is impressed with the comparative weakness of the means adopted by the designers to stiffen and bind together the massive plates of which these columns were built up into a single member.

Let us look for a moment at the construction of the compression chord members of this bridge. They consist substantially of four massive plate webs or girders, each made up of four rolled plates, stitch-riveted together to form one built-up plate nearly 4 ins. thick. Each of these is finished with an angle at top and bottom, and these four long thin girders are supposed to be stiffened and bound together so as to act as one member by latticing on the top and bottom made of 4 × 3-in. 8½-lb. angles. The accompanying



sketch will give an idea of the construction; and full detail drawings of the member are given on another page of this issue.

The point to which we would direct attention is the small size of the angles which are supposed to lattice these four massive webs into one member compared with the size of the webs themselves and, of course, of the load the whole member has to carry. Near the ends of the member, it is true, a long, heavy cover plate replaces the latticing angles; and it is very noticeable in the wreck how vastly more efficient a plate covering is than angle latticing to hold members in place against heavy punishment.

Of course it may be urged in defense of this design that comparatively little material is needed to hold members rigidly in line when subject to direct compression. In theory this is true; and it would be true in practice if all the parts of a compression member were absolutely true, free from all initial strain, and if the load upon them were applied with absolute exactness. Such conditions do not and cannot obtain with even the best workmanship. All our plates and angles have to be straightened after coming from the rolls. Shearing, punching and riveting all set up initial stresses. Every joint in our structural work is far from mathematical perfection. There is no doubt, then, that the stiffening lattice or web that binds the parts of a strut together ought to be in proportion to the parts which it holds.

But the evidence that carries most conviction is the evidence of actual trial, and it is this evidence that indicates the latticing of these chord members to be inadequate. Lower-chord member 9A at Quebec was found bowed out of line on Aug. 27 *because the latticing and the rivets that held it were not strong enough and stiff enough to hold the four webs in place and make them act together.* And if the latticing was not strong enough for its duty here—even granting previous injury to the member—was it strong enough for its duty elsewhere?

Everyone has heard the old jingle:

> For want of a nail the shoe was lost;
> For want of a shoe the horse was lost;
> For want of a horse the rider was lost;
> For lack of the rider the battle was lost;
> By loss of the battle the country was lost;
> And all for the loss of a horseshoe nail!

The Quebec bridge, like any other bridge, was no stronger than its weakest main member. All its main compression members—posts and chords alike—were made up of thin webs which independently of each other were too flexible to have borne any end compression of consequence. All of them, therefore, depended absolutely for their rigidity and stiffness to resist compression without flexure and failure upon the lattice bars by which they were connected, and these in turn upon the rivets that held them. The same thing is true, undoubtedly, of all our struts and columns in all our bridges and buildings; but it is well to have the fact brought clearly and forcibly home to the comprehension of every engineer who has anything to do with structural work.

Was this latticing on these huge columns strong enough for the work it had to do? What does the profession know about the stresses in column latticing? Where in engineering literature has its proportioning been carefully and soundly discussed? If practical experience shows, as may be claimed, that ordinary practice in latticing is good and safe, how shall we safely bridge the gap between the strut in an ordinary bridge designed to carry a load of say a million pounds and these huge columns carrying more than twenty times as much?

Should the latticing be proportioned to the cross-section of the members which it holds in line? Then these 8½-lb. angles on a member with 781 sq. ins. cross-section would correspond to single lacing bars only 1 in. × ⅛-in. on a strut one-fortieth as large, say of 20 sq. ins. cross-section, or a pair of 15-in. 33-lb. channels.

Again, how should the proportions of lattice-bars be varied with the variation in the length of the member? Are the lattice-bars to be considered like the web-members of a truss, since their office is to hold the several ribs they connect from bending? If so, the long column like the long span bridge would seem to require latticing heavy in proportion to the column's length.

Still again, what relation does the great depth of these webs bear to the security of the latticing? We know that a thin flat plate has little stiffness to resist end compression. In broad plates secured by latticing only at their edges and subjected to end compression, is there possibly some deforming action near the center of the plate which does not occur in the comparatively narrow plates used in ordinary columns?

What, if any, were the computations by which the designers of this bridge assured themselves of the sufficiency or supposed sufficiency of this latticing? On what assumptions were their computations made and can these assumptions bear the criticism of the profession?

Such are some of the questions which surely arise wherever engineers are studying the failure of this huge structure; and an answer to which cannot be given without venturing on debatable ground. And to answer with entire certainty these questions which are troubling the profession we must have something more and better than mere computations of the stresses in column latticing, important though these are at the present juncture. It will not be possible, we believe, to reassure either the public or the engineering profession as to the actual strength of such huge columns until actual tests are made upon them.

There will be those, very likely, who will follow other theories of the Quebec failure, and who will claim, notwithstanding the facts above set forth, that special and peculiar weakness in some failing member—due to previous accidents, deficient field riveting or other cause, made it far weaker than its fellows and caused the wreck.

Whatever support may be given to such theories, this one bald fact remains: That all the great compression members in the Quebec structure rest under a cloud of suspicion, and that suspicion can only be removed in the way we have pointed out—by actual tests.

And now, before one goes on to censure the designers who proportioned these huge members, and all the distinguished engineers of deservedly high reputation who approved the design, let us reflect how weak we are, all of us in the profession, in our actual knowledge of the strength of full-size columns, except as we are crudely taught by costly experience in failures of engineering works.

How many thousands of engineers, as they

realize at times the heavy responsibilities that they carry for the safety of life and property, have longed for records of tests of full-size columns such as they are obliged to use in their works. The designers of the Quebec Bridge had to build up a column of steel plates and shapes to carry a load at the ninth panel of the lower chord, of 22,000,000 lbs. They had for a guide the accepted theories of column stresses based on tests made a generation ago on columns of trifling dimensions.

We do not mean to indict the soundness and general reliability of the accepted column formulas, for members of ordinary size where past experience serves as a check and safeguard. We do believe, however, that for the columns of massive dimensions such as are being more and more called for by present-day demands in bridge and building construction, theory needs to be supplemented by actual tests.

When one considers the vast amount of life and property whose safety is at stake, the funds necessary to build a testing machine big enough to test the ultimate strength of the largest column now made ought to be forthcoming at once. Such tests are needed—we may almost say they are necessary—to give the engineer confidence in his own work as well as to give the public confidence in the work of the engineer.

This very crossing of the St. Lawrence at Quebec is the best illustration. Public convenience urgently demands the construction of a bridge at this point. Engineers know that no mistake was made in the choice of the cantilever instead of the suspension type for this work. The disaster of Aug. 29, however, has given a shock to public confidence impossible to overestimate. How can this confidence be restored? We can conceive of no better way than by spreading before the public the exact facts. Let it be frankly confessed that the disaster to the partially completed structure was due to engineers' inadequate knowledge of the strength of huge compression members and to that alone. Let the public understand that if the engineer can have adequate means to test these great columns, he can build with safety and certainty where before he was groping in the dark.

LETTERS TO THE EDITOR.

The Quebec Bridge Disaster.

Sir: I have been a subscriber and constant reader of your journal for a number of years, have followed the development of your staff of writers and have constantly admired the growth of a concise, accurate and comprehensive style of descriptive writing in connection with large engineering subjects, and in this particular I take this opportunity of congratulating you upon the marvelous manner in which you have furnished the engineering profession with a clear and accurate description of the lamentable failure of the Quebec cantilever bridge. The impossibility of the ordinary journalistic writers conveying any real information to engineers is too well known to require comment.

It must be apparent to all broad-minded, clear-thinking engineers that much of the real development of engineering as a whole and the safeguarding of the professions against such failures as the one referred to must come from a clear, frank and accurate distribution of the facts, however regrettable, relative to such failures in engineering structures. I therefore think it is particularly timely to commend your organization which has shown such a development as to fully meet this demand.

Yours sincerely,

William T. Donnelly, M. E.

132 Nassau St., New York, Sept. 7, 1907.

Sir: Your thorough treatment of the Quebec disaster is admirable both in extent and form.

As a designer of cantilever bridges in South America, Alaska, and elsewhere, I looked back over the published details of the Quebec structure the same day we received news of its failure. I saw nothing to criticize in the design except the local transverse connection of the four webs of the open latticed bottom chord.

I believe such tremendous total strains and sections demand cellular construction by solid cover plates and intermediate gussets, and I recall the cellular construction of the compression flange of the original tubular bridge and of the cylindrical compression members of the Firth of Forth cantilever as examples of safe construction under high compression.

I made known to several of my acquaintances, including the designer of our second American cantilever, Edwin Thacher, M. Am. Soc. C. E., my opinion that the wreck of the bridge could be traced to this lack of transverse stiffening in the bottom-chord members. Your Fig. 22 on p. 264 precisely illustrates the effect of the weakness that I pointed out.

Many bridges of one-tenth the span and one-twentieth of the total chord strain have as many rivets in their chord lattice as would be found in the Quebec bridge, and generally will have a solid cover plate on one side.

Perhaps this opinion may have some influence in bringing about a substantial agreement of our sorrowing profession as to the cause of the disaster, and as to the compression details which should be avoided in future important structures.

The application of cover plates and gussets would apparently be feasible even to the already completed members of the yet unerected half of the Quebec bridge.

Very truly yours,

H. S. Wood, M. Am. Soc. C. E.

North American Dredging Co., Park Row Bldg., New York City, Sept. 5, 1907.

Sir: The appalling disaster at Quebec has sent a thrill of keen regret to the heart of every engineer in the country. The feeling manifests itself not only in sympathy for the lives sacrificed and for the loss of a noble structure, but the sudden fall of the latter appears to the professional man also like a severe blow to the reputation of American bridge-builders.

The melancholy facts were to the mind the more oppressive because the causes of the calamity were wrapped in a seemingly impenetrable darkness, in which imagination alone struggled on, trying to find an explanation in some unknown mystic force of nature, which might break forth in other places at any time, without warning, and repeat this disaster.

Your admirable articles in your issue of Sept. 5 have lifted the veil. Though there is no absolute certainty that you have discovered the origin of the collapse of the bridge, the observations on the spot by your representative are so precise and minute, your reasoning so logical, and all circumstantial evidence so convincing, that the writer believes you have correctly located the place in the structure where the first failure occurred.

Your conclusions have, as the writer feels, given great relief to the mind of the engineering profession; not that the regret is less keen or the sympathy less sincere, but in so far, that we may say now with a high degree of probability: there was no miscalculation, no fallacy in theories, no mistake in the erection plan, no error of judgment which could fix any blame on the engineers, consulting engineers or superintendents; but the cause of the calamity was simply and clearly a case of negligent inspection!

Unfortunately, manufacturers are frequently responsible for imperfect inspection. If an inspector had condemned bottom chord A9L because it had a kinked rib and was injured by a fall, he would probably have been hooted down, laughed at, or considered a tyrant who "unnecessarily" cause expense and retarded the work. Now we have the facts. Are not the injuries to this chord, received before it was placed in the structure, the cause of its weakness, so that it buckled to the extent of 2 inches? And were three days not sufficient time for applying means to prevent further buckling?

The experience of the writer's inspector at different works was of the kind as described above, and this letter is written in the interest of all inspectors, who altogether have a hard position. If an inspector neglects his duty, he betrays the confidence of his employer, for which he must account to his own conscience; and if he does his full duty, according to his best judgment, he comes in conflict with the manufacturer, who invariably has a different, though in his opinion a little superior, judgment.

The writer believes that your articles, giving the probable cause for this great calamity, have proved that the judgment of an inspector who insists on absolutely straight and sound compression members, without kinks or injured material in any part, is better than that of the manufacturer, who is apt to consider these matters as insignificant.

Wilhelm Hildenbrand.

1 Broadway, New York, Sept. 6, 1907.

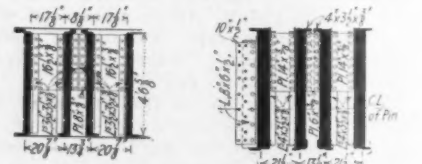
Sir: Referring to your issue of Sept. 5, regarding the failure of the Quebec bridge, your reasoning is all based on the assumption that the chord-member A 9 L was the initial cause of the failure. There is no evidence to support this, other than that the member ultimately failed. To be sure this member shows evidence of being crippled by an extraordinary load, and there is no doubt that all of the members in the anchor arm were subjected to the same conditions at the instant of failure, but it so happened that this member A 9 L had an initial distortion, so that at the instant of failure it absorbed the bulk of the great dynamic energy of the falling cantilever arm. The fact that the structure, as a whole, dropped vertically, points to other causes for failure than the collapse of a single member in one truss.

In all cantilever bridges with curved chords, during the process of erecting the bridge, an anomalous condition arises with regard to the web members when the traveler stands out on the end of the cantilever arm. Similar conditions may arise in a finished structure, but in the Quebec bridge, at the time of the failure, this condition was intensified by the presence of two travelers on the end of the cantilever arm, and at the same time a large part of the fixed load in the floor was omitted. In other words, the condition of the loading which produces large pier moments with comparatively small shearing forces, in a cantilever arm with curved chords, develops a very critical condition in the web members near the tower unless these members are qualified to resist either tension or compression.

In the Quebec bridge, beginning at the tower, the first diagonal web member, on either side of the tower, is a stiff member. Passing on to the end of the cantilever arm, the remaining diagonal members are purely tension members. What point is the criterion for these members for the condition existing at the time of the failure? To be sure, the designer of this bridge made a stress diagram for the conditions covering the erection of this structure, but were those conditions faithfully carried out? Did he provide for one traveler or two travelers on the bridge at the same time? Did he assume the distribution of the fixed loads correctly? Were the shipping weights of the finished members the same as the calculated weights, within reasonable limits? All these things and many more militate against him, and unless he fully appreciates the gravity of the case he will go astray. Now, what can happen if all this is not provided for? If the stress diagram shows a member, near the tower, just at the point of turning from tension to compression, or neutral, this member is in a very critical condition when the chords have an extreme curvature. Any departure from the loading assumed, especially at the criterion, works for or against him as the load is increased or diminished at that point. Any slight deviation may mean failure in case the member under consideration is not capable of resisting either tension or compression.

Now, what can happen in case the load on a web member is such that it cannot resist? If the member is an eye-bar and the load is compression, the member will shirk its duty and allow the bottom chord joint to rise. This will occur simultaneously in both trusses, bringing a bending action on the chord sections, and thereby delaying momentarily the fall until they finally yield and allow the arm to drop. At the same time the tower posts will be pushed in at the bottom and pulled out at the top, draging the anchor arm with it, so that the top chord eye-bars will be strung out on top of everything else, just as shown in the views as published. To be sure the anchor arm collapsed, but at the same time it was dragged forward, as is clearly shown by the fact that the portal now lies midway between the anchorage and the main pier where the top chord eye-bars begin. This is not shown in the views published in Engineering News.

All this argument can best be answered by the designer of the bridge, who has all the data at hand, and the writer suggests that he publish a stress diagram giving the stresses of the cantilever arms to correspond as near as possible to the conditions existing at the time of the failure of the bridge.



Cross-Sections of Lower Chord Member A9L.

Yours truly,

J. W. Schaub,
Consulting Engineer.

Monadnock Building, Chicago, Sept. 7, 1907.

[The stresses in the lower section of the second diagonal landward of the main tower are given on the stress sheet thus:

D. L., 2,207,000
L. L., 725,000

Total, 2,934,000
Wind ± 770,000

These are the stresses per truss, in pounds. The dead-load stress is tension, and the live-load stress given is also tension, being the stress caused by full live-load on the anchor arm. Live-load compression, caused by full live-load on cantilever arm and suspended span, may

amount (by rough calculation) to about 100,000 lbs. The loads of the two travelers produce compression in the member, because its center of moments is riverward of the anchorage; but this center lies in the first panel—though from the drawing it cannot be determined very precisely—and appears to be only some 15 ft. from the anchorage. The travelers then will cause a compressive stress in this diagonal not far from 50,000 lbs. Comparing the possible compressions with the dead-load tension, most of which was actually present at the time of the accident, we can see nothing to support the view that this diagonal might have buckled due to stress reversal. The other diagonals, landward of this one, carry tension under all loadings. The possible buckling of a post in the web-system is another matter, but the posts were stiff members and evidently are not questioned in the above letter.—Ed.]

THE FALL OF THE QUEBEC BRIDGE.

Since our last week's account of the fall of the south half of the great Quebec cantilever bridge over the St. Lawrence, nothing has been brought out in public, nor to our knowledge in private investigation, to indicate a cause for the disaster other than that suggested in our last issue, namely buckling of the bottom chord member in panel 9 of the west truss of the anchor arm. Several rumors are current as to other possible causes, but the very general opinion of those who have visited the site is that this chord-member must be held responsible. The chief fact back of this opinion is the present condition of the member in question, whose doubly buckled shape could hardly be produced by any action other than failure under excessive end compression. Whether such excessive load could have been thrown on the member by prior failure of another member, or whether the failure of chord 9 under its proper load threw excessive stress upon the east truss by way of the strong lateral and sway systems, thereby wrecking the east truss, can hardly be determined in a short time. In consequence no categorical assertion on this matter is justified at the present time. The present probabilities, however, point strongly toward A9L as the point of initial failure.

Because of the vital importance of throwing light on the question of how this great strut could have failed under a stress well below its designed load, we have secured two drawings which are reproduced herewith. For these as well as the accompanying photograph we are indebted to the courtesy of Mr. John Sterling Deans, Chief Engineer of the Phoenix Bridge Co. The photograph is dated Aug. 28, and thus was taken only one day before the collapse; in substance it shows the condition of the bridge at the time it was wrecked.

The stress-sheet of the anchor arm, reproduced on the inset sheet with this issue, will be examined with close attention, we are sure. Dead, live and wind stresses for each member are noted on it, also the combined dead and live-load stress and the stress variation factor $1 + \Phi$ which was employed in fixing the allowable unit-stress.

The stresses shown are computed from the total dead-load and railway live-load, i. e., without live-load on roadways, footwalks or electric car tracks; the latter were included only in the calculations for stresses in hangers, sub-diagonals and floor system. The location of the bridge, nine miles from Quebec and two miles from any village, is to be considered in relation to this selection of live-load. The railway load has three alternative intensities and lengths of loading; of these, that arrangement which gave the maximum in any particular member was used to compute the live-load stress in that member. Snow is not mentioned on the stress sheets, but entered into the various possible combinations of loading which were investigated to determine the sufficiency of the sections provided for the several members. Wind stress was figured for 1,000 lbs. per lin ft. on the lower chord and 500 lbs. on the upper (1,700 and 700 on the suspended span, half to be taken as moving load).

DEAD LOAD:

Lumber	2,500 lbs. per lin. ft.
Floor	3,700 lbs. per lin. ft.
Total from floorbeams	6,200 lbs. per lin. ft.
Trusses and bracing, average:	
Suspended span	7,800 lbs. per lin. ft.
Cantilever arm	18,510 lbs. per lin. ft.
Anchor arm	17,880 lbs. per lin. ft.

LIVE-LOAD FOR TRUSSES.—No loading on electric tracks, roadways or sidewalks. Load on railway tracks one of three following:

a. On each R. R. track 3,000 lbs. per lin. ft. unlimited length.

b. On each R. R. track two E-33 locomotives followed by 3,300 lbs. per lin. ft. for a total train length of 900 ft.

c. On each R. R. track one E-40 locomotive followed by 4,000 lbs. per lin. ft. for a total train length of 550 ft.

LIVE-LOAD FOR HANGERS AND SUB-DIAGONALS AND FLOOR SYSTEM:

On each R. R. track two E-40 locomotives followed by 4,000 lbs. per lin. ft.

On each electric track a succession of two-axle cars 30 ft. long, each equivalent to 56,000 lbs. on two axles 10 ft. c. to c.

On each roadway 24,000 lbs. on two axles 10 ft. c. to c.

WIND LOAD:

Top laterals	500 lbs. per lin. ft.
Bottom laterals	1,000 lbs. per lin. ft.

The allowed unit-stresses were calculated in a somewhat complex manner, an allowance for impact being included in the formula, as will be seen. The principal members were computed by the following formulas for allowed unit-stress (lbs. per sq. in.).

For Tension Chords and Diagonals, and Compression Chords when l is less than 50 r:

$$p = 12{,}000\left(1 + \frac{\text{Minimum Stress}}{\text{Maximum Stress}}\right)$$

For Main Posts:

$$p = \left(12{,}000 - 50\,\frac{l}{r}\right)\left(1 + \frac{\text{Minimum Stress}}{\text{Maximum Stress}}\right)$$

For Wind Members:

$$p = 20{,}000 \text{ lbs. tension in, or} \left(20{,}000 - 90\,\frac{l}{r}\right)$$

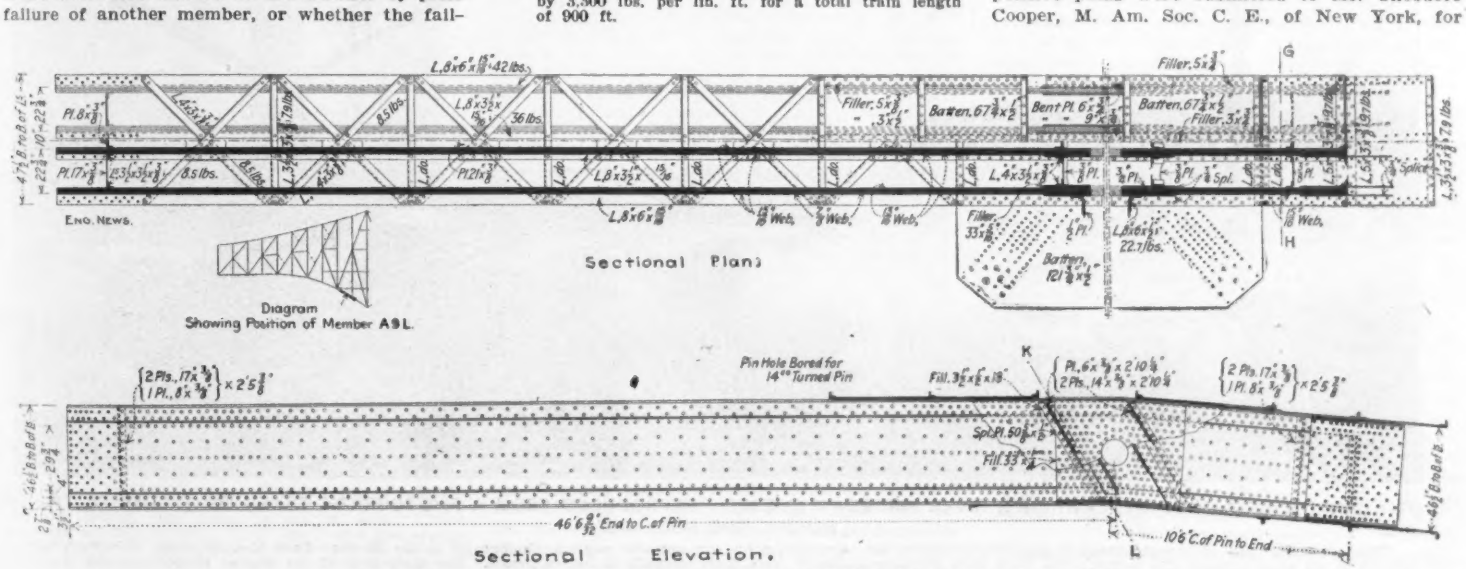
in compression.

In the first two, the parenthetical expression involving the ratio of stress variation is denoted by $1 + \Phi$ on the stress sheet, being calculated and given separately for each member. For the compression chord of the anchor arm, this value is seen to run from 1.5 to 1.7. With $1 + \Phi = 1.6$ the allowed unit-stress would be 19,200. For a member carrying only dead-load, the expression would be equal to 2, giving a unit-stress of 24,000 lbs. per sq. in.

In any main truss member, the unit-stress thus determined is applied to the maximum combination of dead and live-load stresses. As we understand the matter, the effects of wind and snow and of increased live-load were considered in another way. It was required that with the worst combination of loading which seemed a reasonable possibility, including possible future increase of live-load by 50%, the unit-stresses should not exceed 24,000 lbs. per sq. in. Where the computed sections gave a higher stress, the section was increased. Such a case occurs for example in the notorious chord A9, where the actual section is about 50 sq. ins. greater than the "required section" of the stress sheet.

The specifications under which the design was made appear to be of rather complex origin. The original call for competitive designs for the Quebec bridge, issued by the Quebec Bridge & Railway Co., included a specification. The competitive plans were submitted to Mr. Theodore Cooper, M. Am. Soc. C. E., of New York, for selection of the most desirable, and the design of the Phoenix Bridge Co. was chosen by him. Various modifications of the specifications were suggested by him, and most or all of these were subsequently adopted; but the original Quebec Bridge Co. specification was never thoroughly revised, so far as we have been able to learn.

The chord section A9 which we show in detail has a gross section of about 780 sq. ins. in panel 9. The shop member comprises that portion of 9 lying between the field-splice near chord 8 and pin 9, and that portion of chord 10 from pin 9 to the field-splice. The detail arrangement of the chord section from pin 8 to pin 9 can however be readily constructed from the material given in our drawing. The chord consists of four vertical ribs, uniformly 54 ins. deep and 4 ft. 7½ ins. wide from back to back of outer flange-angles. The ribs are connected by top and bottom batten-plates at the splices, and between these points by double latticing of 4 ×


Sectional Plan.
Diagram Showing Position of Member A9L.
Sectional Elevation.
Pin Hole Bored for 14° Turned Pin
46'6 9/32" End to C. of Pin
10'6" C. of Pin to End

PLAN AND SECTIONS OF LOWER CHORD MEMBER, A9L, QUEBEC BRIDGE.
(Prepared from the Shop Drawings.)

3 × 5/8-in. angles with 3½ × 3 × ¾-in. cross struts. Transverse diaphragms are inserted at either side of shop and field-splice.

The proper strength of this chord under the specifications is 1.73 × 12,000 = 20,800 lbs. per sq. in., or a total of 16,224,000 lbs. for the section of 780 sq. ins. Its total dead-load stress is only 11,249,000 lbs., and in the condition of Aug. 29 the stress must have been somewhat short of this amount. It will be remembered that the deflection observed in this member three days before the collapse was lateral, not up and down, and the buckling which now appears in its remains is also lateral. But in this direction the radius of gyration of the chord is close to 19 ins., which makes its ratio of slenderness = 57 × 12 ÷ 19 = 36, corresponding to a very short column. The figure is of course based on integral action of the column. If the four ribs acted altogether independently, the load at the time of failure would have far exceeded their crippling strength as given by Euler's formula.

It is possible to investigate the conditions of eccentricity which might have existed in this member to produce the observed phenomena. The lateral deflection on Aug. 27 was measured, and was found to be 1⅛ to 2 ins. Taking it as 1½ ins., and taking the load on this strut at the time as 17,500 lbs., it appears that an initial eccentricity of loading amounting to 1⅝ ins. would account for the deflection. Further, with such initial eccentricity, it would require a load of about 28,000 lbs. per sq. in. to bring the extreme fiber stress up to 32,000 lbs. That is, the load on the column would have had to be increased by 60% between Aug. 27 and Aug. 29 to produce failure. Actually, the load was increased only very slightly in this period. The theory therefore is wrong in its assumptions; the assumption of hinged ends instead of fixed ends does not account for so large an error. Perhaps the most extreme assumption is that the four ribs continued to act together as an integral body throughout the deflection, and this assumption, therefore, is doubtless in error.

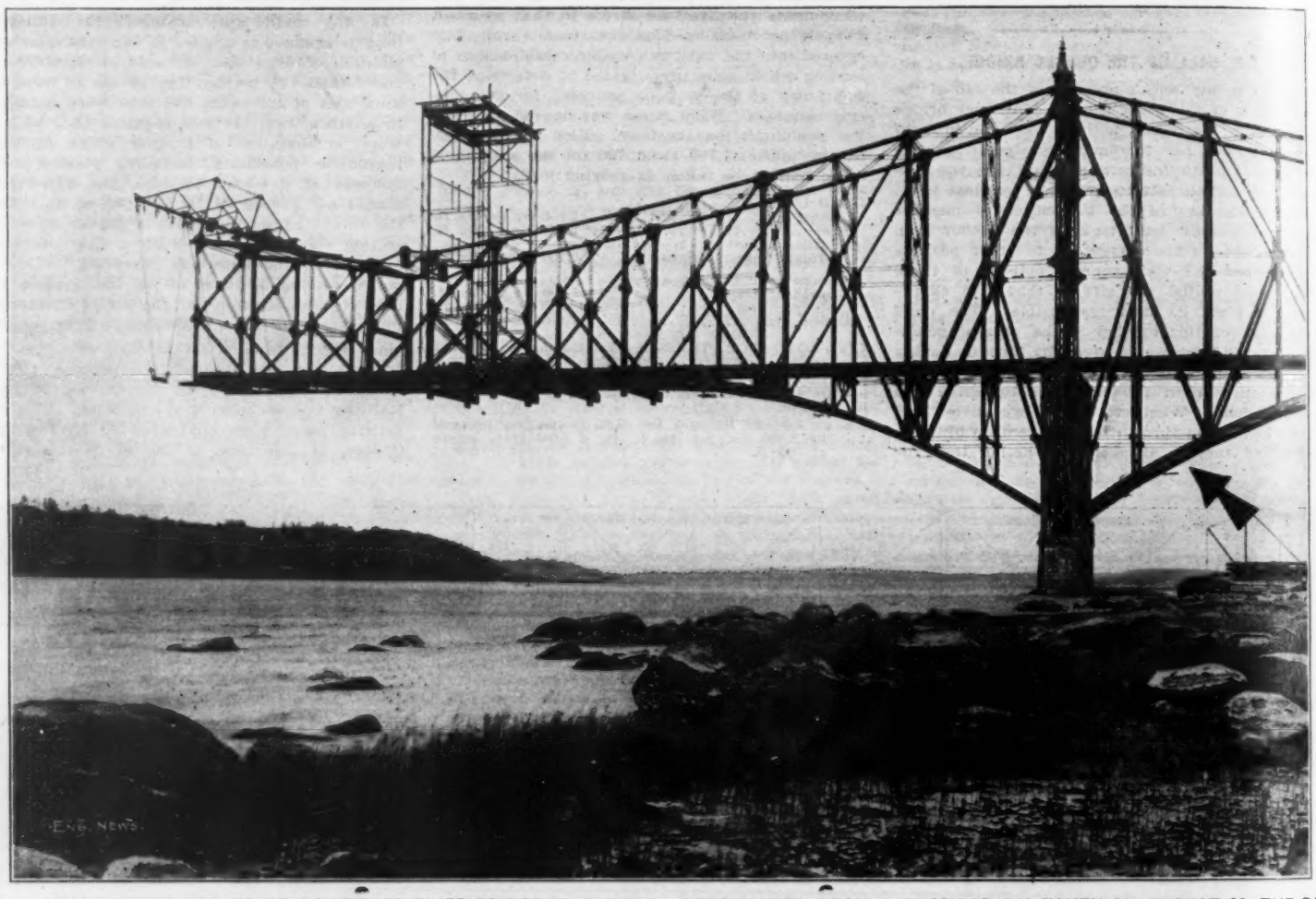
Our purpose here, however, is only that of presenting the drawings and essential data, without attempt at theorizing. The above remarks are given to show that the action involved was not analogous to the buckling of a solid column subject to deflection by eccentric application of load. What other factors of imperfection or accident, besides mere eccentricity, may have operated to bring about the remarkable deflection observed and the subsequent buckling, remains to be brought out by the Canadian Government's investigating commission.

Two official investigations of the accident have been put under way: one by a coroner's jury, the other by a Commission of Engineers appointed by the Canadian Government. The coroner's jury was in session on Sept. 3, 4 and 5 and some interesting testimony was given before it by the engineers who were located at the bridge site, Mr. McLure, representing the Consulting Engineer, and Mr. Kinloch, inspector of material for the Quebec Bridge Co. It was the latter who discovered the bend in chord A9L on Tuesday, Aug. 27. The coroner's investigation was naturally directed chiefly toward determining the responsibility for the failure to stop work on the bridge when the condition of this member was discovered. It would appear from all the testimony that in the conference made up of Kinloch, McLure, Yenser, the foreman in charge of erection, and Birks, the Resident Engineer in charge of the movements of the traveler, it was Birks' opinion chiefly that allayed the alarm felt when the bend was first discovered. The first two men felt that the bend was a grave matter; Yenser also appears to have been frightened by it but to have been reassured by Mr. Birks' confidence. The situation was reported by Mr. McLure on Tuesday evening to Mr. E. A. Hoare, Chief Engineer of the Quebec Bridge Co.; and he went to the bridge the following morning. On the witness stand Mr. Hoare said:

Mr. McLure brought me sketches showing the bend in No. 9 lower chord of the west truss on Tuesday evening. We didn't consider it at the time a serious condition of the work. I visited the bridge the next morning, Wednesday, and went over the whole structure with Mr. McLure and Mr. Kinloch, as well as the Phoenix Bridge Co.'s engineer, Mr. Birks. We discussed the matter together. The engineers on the bridge had just finished checking the levels of all panel points and the alinement of the center post and had found the positions to agree almost perfectly with the designers' calculations.

After ascertaining the condition of that chord, I sent Mr. McLure to New York and to Phoenixville, as the telegraph service, on account of the strike, was too slow for discussing the matter.

Q. You never thought the condition of that chord was a very serious thing?



SOUTH CANTILEVER ARM OF ST. LAWRENCE RIVER BRIDGE AT QUEBEC. REPRODUCED FROM A PHOTOGRAPH TAKEN ON AUGUST 28, THE DAY BEFORE THE COLLAPSE.

(The enormous size of the structure is graphically shown by reproducing on the opposite page a photograph of the 30-story Park Row Building, New York City, reduced to the same scale as the bridge. The Park Row Building is 386 ft. high from sidewalk to top of cupola. The main post of the Quebec Bridge was 315 ft. long c. to c. of pins, and its top was about 400 ft. above water level. The small specks on the horizontal stiffening strut in the anchor arm, just to the right of the center-post, are a man, a rivet-forge and a barrel.)

A. No; I never thought the condition of that chord serious enough to cause an accident to the bridge.

Q. You cannot say with certainty whether the curvature of that chord caused the accident?

A. I cannot say. I have no opinion to give as to the cause. There has not been sufficient time to investigate and reach a definite conclusion.

Q. Did you ever notice similar curvature on other members?

A. Never of the same extent.

Q. Do you think that chord might have been injured in transportation?

A. We inspected it carefully when received.

Q. Do you suppose the curvature of the chord existed when it was put into the bridge?

A. It is impossible to say until we have more time to investigate.

Q. Is it not a fact that the curvature in that chord was recent?

A. I got two reports on it, one from Mr. Kinloch and Mr. McLure that it was recent. The other from Mr. Birks that it was of long standing. I have not yet formed an opinion as to which was correct.

Q. Do you consider that that curvature should have been allowed to remain?

A. I do not. It should have been rectified in some way. (In answer to further questions) I have no record of that piece being injured prior to being placed in the work.

Mr. Norman McLure related the story of the bent chord, his testimony conforming substantially to that of Mr. Hoare. He considered

the condition of chord 9A "serious but not dangerous." When he reached Mr. Deans' office at Phoenixville half an hour before the collapse occurred, he found that Mr. Deans had just received a report by mail from Mr. Birks on the condition of the chord member, and was inclined also to consider the bend of long standing. They were to meet next day for further discussion of the matter, but shortly after leaving Mr. Deans' office, news came of the disaster.

Mr. Kinloch, inspector for the Quebec Bridge Co., repeated the story of his discovery of the bend in the member and corroborated the testimony of Messrs. Hoare and McLure. He examined the bent chord only ten minutes before the collapse occurred. Further testimony follows:

Q. Have you seen that chord which is known to have had a curvature since the accident?
A. Yes.

The Park Row Building, New York City. Reproduced on Same Scale as Quebec Bridge Photograph.

(Part of the St. Paul Building, 220 Broadway, in which the offices of Engineering News are located shows at the right of the photograph.)

Q. In what condition is it?
A. Badly bent up.
Q. Are there any other chords bent up as that particular one is?
A. Not exactly.
Q. Was the deflection in the same direction as the curvature before the disaster?
A. Yes.
Q. Had you any conversation with the engineers regarding this particular chord when you saw the bend?
A. Yes, I showed it to the general foreman [Yenser, who was killed], who, when he saw it, said: "That bend was not here before. I have been over this bridge too many times." Mr. Birks, however, did not think it was very serious, but the general foreman and myself thought it a serious thing.
Q. You saw this chord when it was put into the bridge?
A. Yes.
Q. Was it then the same as the other?
A. Our end of it was repaired.
Q. What necessitated the repair?
A. When they were unloading it, it fell and a few feet broke off.
Q. Where was it repaired?
A. In the bridge yard.
Q. Will you state why after having discovered such a serious state of affairs work was not stopped on Thursday morning?
A. I had not the power to stop it, but it was generally understood that no more steel would be put up until engineering advice could be secured.
Q. Was there any more steel put up that day?
A. No.
Q. Was there any question that day of not moving out the traveler any further?
A. Yes, Mr. McLure and I did not want to move it out.
Q. What did the engineers think about moving out that traveler?
A. They did not consider it dangerous.
Q. And was the traveler moved out?
A. Yes.

Mr. Hoare, recalled, was asked:

Q. Who had the authority to stop the work?
A. The order should come through Mr. Deans, the chief engineer of the Phoenix Bridge Co.
Q. Could anybody else order it stopped?
A. The general foreman in the yards could have stopped it also.
Q. Were you aware that the chord, which was later found to be bent, had been repaired on account of having been damaged?
A. Yes; and report was made that it was in perfect order after the repairs were made.

A painter employed on the bridge testified to having seen a crack in a lateral plate near the main shoe. The plate was ¾-in. thick, 6 ft. square and the crack was some 20 ins. long. Messrs. McLure and Kinloch testified however that what the painter had seen was not a crack but a crimp in the plate and that it could not in any way have affected the strength of the bridge or caused the accident.

The inquest was then adjourned indefinitely to await the progress of the Government Commission's investigation, which began on Monday, Sept. 9.

DERAILMENT of a Chesapeake & Ohio train near Kanawha Falls, W. Va., on Sept. 2, killed five and injured eleven persons. The derailed coaches went down the embankment and nearly entered the Kanawha River.

A DELIBERATE WRECKING of the St. Petersburg-Berlin express, near Berlin, was reported on Sept. 4. Bolts had been removed from the fish-plates at the point of the wreck; the train was derailed, several cars were telescoped, and eleven persons injured.

ELEVEN WERE KILLED and as many were injured in a wreck on Sept. 6 on the Chicago, Rock Island & Pacific Ry., at Norris, Iowa. An express train making up time left the rails and struck the locomotive of a freight on the siding. Practically all those killed were in the smoker, which, of light construction and coupled up between the mail car and a Pullman behind it—both heavily built cars—seems to have been smashed like an egg by the impact.

INCAUTIOUS SPEED on a dangerous curve of the Canadian Pacific Ry., at Horseshoe Falls, near Orangeville, Ont., apparently caused the bad wreck there on Sept. 3. Six persons were killed and about 50 injured. The curve is known as the Horseshoe curve, and while in trackage it is a mile in length its extremities are only about 200 yards apart; it is a transition curve, and the upper end is about 60 ft. higher than the lower. The train was running down grade, and road officials admit that the speed was excessive.

A FIRE-DAMP EXPLOSION is reported from Monterey, Mex., to have occurred in the Esperanzas mines, near Musquiz, Coahuila, on Sept. 6. Twenty-seven miners are reported to have been killed, and later dispatches say that 200 men are cut off from escape by the fire that followed the explosion. On the following day an explosion of gas occurred in West Frankford mine No. 11, of the Dering Coal Co., of Benton, Ill. In this explosion 23 miners were badly injured.

THE "LUSITANIA," the ship on which all eyes are turned for the moment, was reported by wireless telegraph via Sable Island station at 5 a. m., Sept. 11. She was then 1,189 miles east of Sandy Hook, or, on the course she is sailing, 1,591 miles west of Daunt Rock. She left Daunt Rock at 12.10 p. m. on Sunday, Sept. 8 at 9 a. m., Sept. 11, then, she had been steaming 68 hrs. (allowing time correction). That makes an average of but 23.4 knots per hr. for the elapsed time when she was first spoken from this side; but the thick weather which held for some time after her departure necessitated holding her in check. Between 9 p. m. on Sunday and noon on Monday she covered 376 nautical miles, which means a speed of 25 knots per hr. for 15 hrs. She reported by wireless via Crookhaven on Sept. 9 that the day's run ending at noon had been 561 knots—despite the fog—or at an average rate of 23.4 knots per hr. Calculations made by the steamship company indicate that, nothing occurring to retard her, she will reach her pier at 7 a. m. on Friday, Sept. 13, passing Sandy Hook at 1 a. m. This would lower the record held by the "Deutschland" by about 3½ hrs.

THE PITTSBURG WATER FILTRATION PLANT was not completed on Sept. 1, as was expected. It is hoped that considerable portions of the plant may be in operation before the end of the year, and that the whole plant will be ready for use by the spring or early summer of 1908.

PANAMA CANAL WORK DURING AUGUST is summarized in a cable dispatch to Washington from Chief Engineer Goethals thus: Excavation at Culebra, 786,866 cu. yds.; excavation at Gatun, 105,225 cu. yds.; excavation at Mindi, Chagres and La Boca, 24,861 cu. yds.; dredging in canal, Colon division, 189,120 cu. yds.; La Boca division, 168,284 cu. yds.; total dredging, 357,404 cu. yds. This makes a total excavation of 1,274,404 cu. yds., the largest monthly amount since the American occupation. Although the rainfall was 11.89 ins., against 9.5 ins. in July, the total excavation in August was 215,628 cu. yds. more than in the month next preceding, which up to that time had broken all records.

A PARTY OF ENGINEERS, designated by the German Government as a commission to inspect electric railways and high-tension transmission systems of this country and Mexico, arrived in New York on Tuesday, Sept. 2. The systems of the New York Central, New York, New Haven & Hartford and the Long Island Railroad and of the Interborough Rapid Transit Co. were inspected. The party proceeded to Boston, and later to Schenectady, where they were entertained by the officials of the General Electric Company, and shown through the various departments of the Schenectady works. The commission was composed of the Prussian Privy Councilor Wittfield; Professor W. Reichel, of the Royal Technical University; Director Frishmut, of the Siemens-Schukert Works; Directors Elfes and Pforr, of the Allgemeine Electricats Gesellschaft, and Director Jordan, of the Lahmeyer Works.

THE USE OF RAILS 60 FT. LONG for electric interurban railways is proposed in connection with the construction of a line of this character intended for very high speeds with heavy cars. Regular freight trains are also to be operated. The line will be 40 miles long, and the fast trains will make the run in 55 minutes, including three intermediate stops. The purpose of the long rails is to make a smooth and easy-riding track by eliminating 50% of the rail joints as compared with ordinary 30-ft. rails. Rails of this length have been used extensively in street railway tracks, and on the interurban lines of the Indiana Union Traction Co. In the latter case, however, it is reported that the results were not satisfactory, the cost of maintenance being unduly high. Rails of this length were at one time advocated for steam railways, but are not used to any extent, although the Norfolk & Western Ry. has had satisfactory experience with 60-ft. 85-lb. rails of the Am. Soc. C. E. section.

THE KINZIE ST. DRAWBRIDGE of the Chicago & Northwestern Ry., crossing the north branch of the Chicago River at the entrance to the passenger terminal, has been converted from an equal-arm swing bridge to an unequal-arm or "bobtail" bridge. All the terminal traffic passes over this double-track bridge, and to relieve the present congestion a four-track bascule bridge is to be built. The first half of this will be a double-track structure parallel with the present bridge, but this could not be erected without fouling one arm of the swing bridge. The latter has, therefore, been changed as above noted. The short arm is fitted with rollers running on a track laid on the guard pier, and wooden boxes loaded with pig iron are mounted on girders resting on the ends of the top chord. A trestle approach has been built in the east channel. The swing bridge is a through bridge, with two riveted lattice trusses of 190-ft. span. About 60 ft. of one arm has been cut off. The work was done on Sept. 1, in less than nine hours, large gangs of men being employed. The bridge was swung open, and the portion to be cut off was blocked up on the timbers of the guard pier. The smaller members were then severed with hack saws, while the chords, etc., were cut by drilling rows of holes with pneumatic drills. At the same time the temporary fixed approach was being built across the east channel. The present bridge was built in 1898.

OBSERVATION STREET CARS have been in operation for two seasons in Montreal, Canada, according to the "Street Railway Journal" of Aug. 31. The Montreal Street Railway Co. operates these two cars every afternoon and evening (including Sundays and holidays) through some of the more attractive parts of the city and around Mt. Royal. The trip occupies about an hour and the fare is 25 cts. The cars are built entirely open and the seats are arranged in steps, so that each passenger has an unobstructed view. The average income on week days is about 45 cts. per car-mile and as high as 60 cts. on holidays. The total income for the summer season of 1906 was about $3,323 per car. The total of wages paid in this season for operating each car was about $377. The cost of maintenance and repair has been negligible.

FOREIGN LETTER POSTAGE RATES will be reduced after Oct. 1. The new rates, which were agreed upon at the Universal Postal Union at Rome in May, 1906, are less than those heretofore obtaining by 50% or more. Instead of a rate of 5 cts. per each half ounce of weight, as at present, the rate will be 5 cts. for the first ounce and 3 cts. for each additional ounce. A system of return-postage coupons will also be inaugurated, enabling persons wishing to enclose return postage to their correspondents abroad to purchase coupons, at a trifling premium, redeemable in certain foreign countries for the stamps of those countries.

PERSONALS.

Mr. Carroll Preston Cooper, General Superintendent of the Southern Ry., has been promoted to the position of Manager of the St. Louis and Louisville lines.

Mr. Robert Hauxhurst, Jr., Assoc. M. Am. Soc. C. E., M. Am. Inst. M. E., has been appointed General Manager of the Poderosa Mining Co., of Antofagasta, Chile.

Mr. A. F. Keller, Chief Engineer for the Mesta Machine Co., of Pittsburg, has resigned. He will take a position at the Gary plant of the U. S. Steel Corporation.

Mr. M. S. Monroe, General Foreman of Locomotive Repair for the Chicago, Lake Shore & Eastern Ry., has been appointed Master Mechanic. The former office has been abolished.

Mr. H. S. Jones, General Superintendent of the Mobile, Jackson & Kansas City R. R., has been made Chief Engineer, with offices at Mobile. The former position is abolished.

Mr. A. H. Beale has resigned as General Manager of the Pottsville works of the Eastern Steel Co. Mr. Wm. Melhorn, former Mechanical Engineer with the Pencoyd Iron Works, succeeds him.

Mr. Wm. D. Marks, M. Am. Inst. E. E., expert in gas and electricity for the Corporation Counsel of New York City, has removed from Philadelphia and opened offices in the Park Row Building, New York City.

Mr. J. E. Murphy, Acting Resident Engineer of the Southern Pacific Co. for Louisiana, has resigned. Mr. John Murphy, Roadmaster of the Houston & Texas Central R. R., at Corsicana, Tex., succeeds him.

Mr. Theodore P. Bailey, Assoc. M. Am. Inst. E. E., formerly Assistant General Manager of the General Electric Co., in charge of their Chicago office, has been appointed General Manager of the Kobusch Automobile Co., of St. Louis.

Prof. Ulysses S. Grant, M. Am. Inst. M. E., of the Chair of Geology at Northwestern University, at Evanston, Ill., has been appointed Acting Dean of the College of Liberal Arts of the University during the absence of Dean T. F. Holgate for a year abroad.

Mr. Harry G. Raschbacher, Jun. Am. Soc. C. E., has resigned as Chief Engineer of the Wyoming Central Irrigation Co. to accept the position of Assistant Chief Engineer of the California Development Co., in charge of the design of reinforced-concrete structures.

Mr. Julian C. Smith, recently General Superintendent of Construction for Dodge & Day, of Philadelphia, has resigned that position and acquired a controlling interest in the Atlantic Engineering & Construction Corporation, of Norfolk. The name of the latter concern will be changed to The Atlantic Co., Inc.

Mr. F. E. Golian, who for some time has been connected with the engineering department of the Virginia Bridge & Iron Co., of Roanoke, is to take charge of the new contracting office of the company at New Orleans. That office supersedes the one heretofore located at Little Rock, which will be discontinued.

Mr. C. D. Sternfels, who for three years has been at the head of the publicity department of the Arthur Koppel Co., of Pittsburg, on Sept. 16 will assume charge of the newly inaugurated publicity department of the Standard Roller Bearing Co., of Philadelphia.

Mr. H. M. Hallock, General Superintendent of the Choctaw district of the Chicago, Rock Island & Pacific Ry., extending from Memphis to Amarilla, Tex., and from Caldwell, Kan., to Ft. Worth, has resigned. He is only 33 years old, being one of the youngest men in the country in a position of such responsibility.

Mr. George H. Bartholomew, formerly connected with the law firm of Cravath, Henderson & de Gersdorf, New York City, has been appointed assistant attorney on the Isthmus, for the Isthmian Canal Commission and the Panama R. R. Co. Mr. Bartholomew is a graduate of Yale and a citizen of Connecticut. His appointment was effective Sept. 10.

Messrs. J. G. Ellendt and O. L. Griffith have severed their connection with the Concrete Engineering & Supply Co., of New York City, and, together with Mr. C. E. Tirrell, have organized the J. G. Ellendt Co. The new company will engage in consulting engineering and in contracting on reinforced-concrete work, with offices at 1 Madison Ave., New York City.

Mr. Chas. C. Gilchrist, Assoc. M. Am. Inst. E. E., Engineer in charge of designing at the New York works of the Western Electric Co., has been commissioned by the company to spend a year in Europe for the purpose of studying European manufacturing methods and conditions from the engineering viewpoint. Mr. and Mrs. Gilchrist will sail from New York about Oct. 1. The company has five factories of its own in Europe, and offices besides in various European cities.

Mr. Olin H. Landreth, M. Am. Soc. C. E., M. Am. Soc. M. E., Consulting Engineer and Professor of Engineering at Union College, Schenectady, N. Y., recently severed his connection as Consulting Engineer of the N. Y. State Department of Health, which position he has held for ten years. He has also been granted leave of absence for a year from his teaching duties, and will devote himself to professional work in hydraulic and sanitary engineering and to the work of the recently organized Albany Sanitary Bureau, of which he is Secretary. The Bureau is a firm composed of three men, the other two being Dr. Willis G. Tucker, Professor of Chemistry and Toxicology at the Albany Medical College, and Mr. James H. Stoller, Professor of Biology at Union College. Occasional services will also be rendered by Dr. Richard M. Pearce, Director of the Bender Hygienic Laboratory and Professor of Bacteriology at the Albany Medical College, as Consulting Bacteriologist of the Bureau.

Obituary.

Nelson A. Sager, M. W. Soc. E., Assistant Engineer in the Intercepting Sewer Department of the city of Chicago, died on Aug. 30. He was 53 years of age and had lived in Chicago for 15 years. He was born at Port Hope, Ont., Canada.

ENGINEERING SOCIETIES.

COMING MEETINGS.

LEAGUE OF AMERICAN MUNICIPALITIES.
Sept. 18-20. Eleventh annual convention at Norfolk, Va. Secy., John MacVicar, 18 Broadway, New York City.

AMERICAN PUBLIC HEALTH ASSOCIATION.
Sept. 30-Oct. 4. Thirty-fifth annual meeting at Atlantic City, N. J. Secy., Dr. Chas. O. Probst, Columbus, Ohio.

AMERICAN SOCIETY OF MUNICIPAL IMPROVEMENTS.
Oct. 1-4. Annual meeting at Detroit. Secy., Geo. W. Tillson, 831 Ocean Ave., Brooklyn, N. Y.

NATIONAL ASSOCIATION OF RAILWAY COMMISSIONERS.
Oct. 8. Annual meeting at Washington, D. C. Secy., Edw. A. Moseley, Interstate Commerce Commission, Washington, D. C.

RAILWAY SIGNAL ASSOCIATION.
Oct. 8-10. Twelfth annual meeting at Milwaukee. Secy., C. C. Rosenberg, Lehigh Valley R. R., South Bethlehem, Pa.

AMERICAN BOILER MANUFACTURERS' ASSOCIATION.
Oct. 8-10. Nineteenth annual convention at Atlanta, Ga. Secy., J. D. Farasey, Forest St. and Erie Ry., Cleveland, O.

INTERNATIONAL ASSOCIATION OF FIRE ENGINEERS.
Oct. 8-11. Thirty-fifth annual convention at Washington, D. C. Secy., Jas. McFall, Roanoke, Va.

AMERICAN ELECTROCHEMICAL SOCIETY.
Oct. 10-12. Annual fall meeting at New York City. Secy., Prof. J. W. Richards, Bethlehem, Pa.

AMERICAN STREET AND INTERURBAN RAILWAY ASSOCIATION.
Oct. 14-18. Annual convention of this and affiliated association at Atlantic City, N. J. Secy., Bernard V. Swenson, 29 West 39th St., New York City.

AMERICAN STREET AND INTERURBAN RAILWAY ENGINEERING ASSOCIATION.
Oct. 14-16. Annual convention at Atlantic City, N. J. (See preceding item.) Secy., S. W. Mower, Southwestern Traction Co., London, Ont.

ASSOCIATION OF RAILWAY SUPERINTENDENTS OF BRIDGES AND BUILDINGS.
Oct. 15-17. Annual meeting at Milwaukee. Secy., S. F. Patterson, Concord, N. H.

AMERICAN GAS INSTITUTE.
Oct. 16-18. Second annual meeting at Washington, D. C. Secy., Jas. W. Dunbar, New Albany, Ind.

ROADMASTERS' AND MAINTENANCE OF WAY ASSOCIATION.
Nov. 11-14. Twenty-fifth annual convention at Chicago. Secy., W. E. Emery, C. & N. W. Ry., West Chicago, Ill.

AMERICAN MINING CONGRESS.
Nov. 11-16. Tenth annual convention at Joplin, Mo. Secy., J. F. Callbreath, Jr., Denver.

AMERICAN CIVIC ASSOCIATION.
NATIONAL MUNICIPAL LEAGUE.
Nov. 19-21. Joint convention at Providence, R. I. Secy., Clinton R. Woodruff, North American Building, Philadelphia.

SOCIETY OF NAVAL ARCHITECTS AND MARINE ENGINEERS.
Nov. 22-23. Annual meeting at New York City. Secy., W. J. Baxter, 29 West 39th St., New York City.

AMERICAN SOCIETY OF CIVIL ENGINEERS.—The first regular business meeting of the fall was held at the society's house on Wednesday evening, Sept. 4. Mr. John C. Hoyt, Assoc. M. Am. Soc. C. E., presented a paper on "Comparison of Rainfall and Run-Off in the Northeastern United States."

NATIONAL IRRIGATION CONGRESS.—Among the papers and addresses presented at the fifteenth congress, the general program of which we touched upon here on Aug. 29, the following may be mentioned as of especial interest: "Conservation of Resources," Gifford Pinchot, Director of the U. S. Forest Service; "National Forestry," Gov. Geo. C. Pardee, California; "Conservation of Soils," W. J. McGee, U. S. Bureau of Soils; "Conservation of Mineral Resources," J. A. Holmes, U. S. Dept. of the Interior; "Conservation of Water," M. O. Leighton, U. S. Hydrographer; "State Conservation of Resources," H. Foster Bain, Director, Illinois State Geological Survey; "The Community Idea in the U. S. Reclamation Act," Morris Bien, U. S. Reclamation Service; "The Work of the National Reclamation Service" (illustrated), F. H. Newell, its Director; "Irrigation and Drainage Investigations," A. C. True, Director Exp. Stations, U. S. Dept. of Agriculture; "Some Things Needed to Secure the Highest Development of the Arid Region," Elwood Mead; "The Greatest Need of Arid America," Samuel Fortier; "Relation of Irrigation to Dry Farming," Alfred L. Roeding, U. S. Dept. of Agriculture; "Irrigation by Private Enterprise," Reed Smoot, U. S. Senator, Utah; "Water Users' Associations," Gov. Jos. H. Kibbey, Arizona; "Municipal Irrigation Systems," L. L. Dewett, Attorney Modesto Irrigation District; "The National Forest Service" (illustrated), Gifford Pinchot.

WESTERN SOCIETY OF ENGINEERS.—The first meeting of the season was held at the society's rooms in Chicago on Sept. 4. The President, Mr. W. L. Abbott, in calling the meeting to order announced that plans were being made to enlarge the society's quarters in order to give greater accommodation for the meetings and the library.

A paper on "Hydraulic Engineering at the University of Wisconsin" was presented by Prof. Daniel W. Mead, M. Am. Soc. C. E. He pointed out that this institution has a rather unusual system of organization, which results in having a larger number of full professors than is generally the case. In some cases also (as in his own department) the step has been taken of obtaining the professor from the ranks of active practicing engineers, and he himself had had no experience in teaching prior to his appointment as professor of hydraulic and sanitary engineering. The paper dealt with two subjects in particular: (1) The ideas of the author in regard to technical education, and the general scheme of instruction as planned and carried out at the university; (2) the construction and equipment of the new hydraulic laboratory, which is on a scale sufficient for practical work.

In the discussion, Mr. Andrews Allen referred to the great advance in the system of engineering education since he graduated from the University of Wisconsin 16 years ago. He obtained the foundation of his education at the institution, but all of his real engineering knowledge was acquired afterwards in practical life. Under the present system the aim is to make the student able to apply his knowledge when he enters practical life. Mr. J. H. Warder referred to a case where water was being charged for on a basis of miner's inches, measured in a very crude manner. By a very simple application of a plank flume and a sharp-edged weir in the ditch, and the use of simple formulas, he was able to show that the company was receiving less than half the amount of water charged for. Mr. Junkersfeld referred to the lack of knowledge of the application of hydraulic principles in pump design. This was very evident in the case of some high-pressure fire pumps; while two designs met the requirements of the contract a third fell far below these requirements, and yet all had been designed and built by firms of high reputation. Mr. E. E. R. Tratman (Associate Editor of Engineering News) considered that the most important feature of the system of instruction as planned by Prof. Mead was in its object of showing the practical application of theories and principles. It is not a difficult matter to teach principles, or for a student to comprehend them in the abstract. The difficulty comes when a problem is encountered, and it is necessary to realize what laws are involved and how they are related to the problem and to each other. This is the sort of knowledge which the engineering graduate has very largely to acquire by "trial and error" after he enters practical life, but it is quite possible so to instruct him during his college career that he will be better fitted to see the relations of theory and principles to practical problems, and so be better able to use his engineering knowledge as a working tool. Mr. Mead spoke on similar lines, and showed that mathematics is not an end in itself, but simply a means to an end, or a tool of theory to accomplish a work of practice. In regard to lack of knowledge of hydraulics and hydrology he referred to a water-power plant which is practically useless because the engineer failed to realize the practical aspects of the principles of the run-off or available flow. A certain average run-off was assumed, but later investigation (made after the plant had been built) showed that the minimum rate was so low and for such a long period that the necessary power could not be obtained.

The list of papers for the season includes the following: (1) "Experimental Determination of Web Stresses in Plate Girders," Prof. F. E. Turneaure; (2) "Recent Developments in Steam Turbines," Prof. J. C. Thorp; (3) "The Nature of Boiler Efficiency," H. Kreisenger and W. T. Ray; (4) "Methods of Computing Quantities and Handling Materials from the Culebra Cut of the Panama Canal," A. L. Zinn; (5) "Fire Protection of Fireproof Buildings," W. C. Robinson; (6) "The Tunnels Under the Chicago River for Electric Cables," G. B. Springer; (7) "The Passing of the Steam Locomotive," W. E. Symons; (8) "Telephone Rates for Large Exchanges," W. H. Crumb; (9) "The History of Electric Lighting," W. D'A. Ryan; (10) "Electric Elevators for High Buildings," J. D. Ihlder; (11) "The Hydro-Electric Development of the Chicago Sanitary District," E. B. Ellicott.

ENGINEERING LITERATURE

Supplement to ENGINEERING NEWS. September 12, 1907.

CONTENTS.

REVIEWS:
Locomotive Compounding and Superheating; Railroad Men's Catechism; Locomotive Breakdown Questions. Reviewed by H. Wade Hibbard.. 291
Practical Advice for Marine Engineers. Reviewed by D. W. Taylor..... 293
Water-Works Management and Maintenance. Reviewed by Dabney H. Maury 294
The Elements of Mechanics..... 295
Instructions to Inspectors on Reinforced Concrete and Concrete Data..... 295
The Limit of Wealth; Socialisms..... 296
The Copper Mines of the World..... 296
Spirals for Street Railway Curves..... 296
The Principles and Practice of Coal Mining.... 297
Guide Du Monteur..... 297
PUBLICATIONS RECEIVED 298

A discussion of government publications of interest to engineers, and how to obtain them, appeared in this Supplement for July. Since that date we have received a number of special lists issued by the Superintendent of Documents, Washington, D. C., which bring together in convenient form the public documents on sale regarding special topics, thus saving possible purchasers the necessity of looking through the whole of the catalog issued by the official named. Included in the pamphlets we have received is one devoted to water pollution and water purification, and another on the publications of the U. S. Geological Survey. These special lists are 4 × 7½ ins., and, being printed in brown, with a somewhat ornamental title-page, their apearance is quite unlike that of the usual government publication.

REVIEWS.

Locomotives.

Reviewed by H. WADE HIBBARD,* M. Am. Soc. M. E., M. Am. Ry. M. M. Assoc.

LOCOMOTIVE COMPOUNDING AND SUPERHEATING.—A Practical Text-Book for the Use of Railway and Locomotive Engineers, Students and Draftsmen. By J. F. Gairns. London, England: Charles Griffin & Co., Ltd. Philadelphia: J. B. Lippincott Co. Cloth; 5¼ × 8¾ ins.; pp. 189; 1 plate and 148 text illustrations. $3, net.

RAILROAD MEN'S CATECHISM.—By Angus Sinclair. Being an Instruction Book for Enginemen, Trainmen, Signalmen and Every Person Connected with the Movement of Trains. New York: Angus Sinclair Publishing Co. Cloth; 4 × 6½ ins.; pp. 200; illustrated. $1.

LOCOMOTIVE BREAKDOWN QUESTIONS.—Answered and Illustrated. By W. G. Wallace, Past-President Traveling Engineers' Association. Chicago, Ill.: Frederick J. Drake & Co. Flexible leather; 4½ × 7 ins.; pp. 285; text illustrations and folding plates. $1.50, net.

COMPOUNDING.

"I don't want to hear a word about compound locomotives," was the emphatic remark to the writer five years ago by a New York railroad president. The author of "Locomotive Compounding and Superheating" frankly acknowledges the ill-repute out of which the compound is so slowly rising, and very early lets the reader see that only a few out of the hundred systems have escaped merited oblivion.

Parallel columns are usuallly impressive, and the method is well employed in the opening pages of this book to dispose of the old argument that because multiple expansion is so universal in stationary and marine practice, therefore it is desirable in locomotives. But railway service is shown to differ from power-house or steamship in ten particulars. Not all designers have been conscious of these limitations, and the results of their enthusiasm or business push have made true the statement that "engineers are more dissatisfied with compound systems than with compound locomotives."

Mr. Gairns is an Englishman. Hence both by natural viewpoint and geographical convenience he is fitted to write for Americans, because England is even less inclined towards compounds than are we, and yet he is in close access to the Continent where they "occupy to-day an assured position," so excellent in economy, reliability and durability that "before many years have passed they will become a standard feature of locomotive engineering in all countries." We here in America are witnessing the transportation economies of the large-capacity steel car which may foreshadow the wide adoption of the Mallet articulated compound for heavy freight service, huge in tractive effort, yet, as on the Erie with its 205 tons distributed upon 16 drivers, easy on the overladen rail and flexible on a curve.

Fourteen pages are devoted to the early history of the compound locomotive, though no mention is made of the American compounds built and used in 1868, 1870 and 1883. With 1889-93 came the period of large expansion into very many designs. At that date each different locomotive-shop engineer in the United States and mechanical superintendent and consulting engineer abroad felt called upon to design and advocate his own compound. Most of these were two-cylinder, the starting, intercepting and reducing valves, and abroad the link and main valve motions, also, differing in degree of complexity. A total of 49 pages is devoted to these 33 types of two-cylinder compounds. Although engines with a greater number of cylinders have been built in large numbers for many years, it is probable that the two-cylinder engines still outnumber all other compound locomotives. The author goes rather fully into the limitations of this engine, and states that it generally needs to be kept rather closely to the special work for which it was designed, lacking flexibility.

Engines with more than two cylinders are then discussed, there being some recent developments, notably in England, in these along the lines of flexibility in varied service.

Twenty-six pages are reserved for four-cylinder balanced locomotives, and very properly so, because "these engines are becoming well-nigh universal, either 'undivided and balanced,' with the four cranks all on one axle, or 'divided and balanced,' with two main driving axles. In fact, almost all recently-designed compound engines belong in this class" Furthermore, "when more than two cylinders are employed, compounding introduces other possibilities besides that of direct economy, and there is little question that it is because of these that compounding is now regarded with greater general favor than formerly." Indeed, European engineers have become so thoroughly satisfied with four-cylinder balanced compounds, having considerably over 2,000 of the de Glehn type alone, that while they recognize Monsieur Mallet in 1876 as the father of the compound locomotive, Monsieur de Glehn might almost lay claim to as great an honor because of his work, in 1891 and subsequently, in its modern and most successful development. In Europe the type is being extensively used for freight as well as passenger service, while in the United States it is being adopted as yet only for the latter. Our first engine was built in 1902 at Baldwin's. Although the earlier American balanced engines were slightly faulty in balance, their action has been corrected, and the experience gained with them has served to turn out a practically perfect locomotive since. As to cost of maintenance for four cylinders and their largely duplicated machinery, the European balanced compound, even in rough freight service, appears not to show any increase over its so-called "simple" competitor. The division of power apparently lessens concentrated strains, wear and breaks.

Mr. Gairns has only eleven pages for articulated compounds, though his next edition will probably give more attention to American developments now big with promise along this line. The Meyer articulated locomotive of 1867 was compounded by Mallet in 1887 for a 2-ft. gage trial curves of 60 ft. radius. The light rail compelled the four driving axles to total only 27,000 lbs. The largest Mallets in Europe are working on the St. Gothard, 0-6-6-0 in type, without separate tender, and weigh 187,000 lbs. In 1904 the Baltimore & Ohio Mallet was built by the American Locomotive Co., a 0-6-6-0, weighing 334,500 lbs. without its tender, followed by a number built at Baldwin's for other roads, notably several 2-6-6-2's for the Great Northern on repeated orders. This summer the Erie has received three 0-8-8-0's, weighing 410,000 lbs., but whose individual wheel load is only 25,600 lbs. Although these Erie Mallets are much heavier and more powerful than the Baltimore & Ohio, the peculiar features of the two designs are substantially alike, none of them having failed to give perfect satisfaction during the years the earlier engine has been in continuous service. They are to be used as pushers up a 1.3% grade, handling a 2,660-ton train, aided by the road 2-8-0 engine. "Compounding has placed the articulated locomotive on a most satisfactory basis," the flexible pipes having to endure low pressure steam only, the locomotive having its two low-pressure cylinders on "an articulated forward motor truck."

The author's concluding remarks on compound locomotives may well be quoted almost in full:

> We have now reviewed every compound system as employed for locomotives, besides dealing with a few suggestions which have never been carried out; and it only remains to devote a few words to a resumé, and to the future probabilities and possibilities. The methods now employed for new locomotives are almost entirely arranged with three or four cylinders; for the two-cylinder systems, with their unequal cylinders, and the necessity for comparatively complicated starting devices to enable the work in the low-pressure cylinder to be equalized with that being done in the high-pressure cylinder when working non-compound, are being superseded very largely by other systems.
>
> At one time the increased complication and greater first cost of engines with more than two cylinders were considered good arguments against the use of three or four cylinders; but it is now argued with success that these factors, though important, are more than balanced by the mechanical advantages as well as the compound advantages of multi-cylinder locomotives. Moreover, with three or four cylinders available, the possibility of using them all with boiler steam on occasions goes far to solve the problem of providing very powerful engines of ordinary dimension. If only for this reason, compounding represents progress. And when the possibility of achieving advantage by the compound use of the steam at ordinary times, that is, for the largest proportion of the time the engine is working, is added to the preceding, it will be seen that it is almost impossible for the compound locomotive to be other than satisfactory if properly designed and handled.
>
> It is therefore only reasonable to prophesy that the next few years will see a great extension of the use of compound engines, especially for hard passenger and freight traffic. In fact, this prophecy is even now in the early stages of its fulfilment.
>
> It appears very doubtful whether triple-expansion engines will ever be employed for locomotive purposes, for to attempt to go beyond two-stage expansion is to invite difficulties (with very little corresponding advantage) owing to the extreme variableness of the working conditions of locomotive operation.

SUPERHEATED STEAM.

According to the preface, "The use of superheated steam for locomotives has assumed such recent importance that a collection of matter relating to the various apparatus in use has not hitherto been presented in any technical book on the locomotive engine." Indeed, the progress has been so rapid that Mr. Gairns' own figures for the number of superheater locomotives must, according to Mr. F. J. Cole, be enlarged from less than 500 in all countries to over 1,600 in Europe, 372 on the Canadian Pacific Railway, and over 60 in the United States.

The introduction states that superheated steam attains nearly the same objects as compounding, experiments in Germany and Canada showing that there is very little added economy in combining a compound and a superheater. The excessively dry steam is so highly over-heated that

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a very much shorter cut-off may be used in one-stage expansion than with wet steam, and yet cylinder condensation be avoided. The resulting low terminal pressure exhausts less power to the stack, the same as compounding. Incidental advantages are found in an increase in volume of the boiler steam, a use of waste heat in some of the less known smoke-box types of superheaters, a greater mobility of the lighter superheated steam through passages and constricted valve openings when the piston speed is very rapid, and the possibility of using lower steam pressures and thus avoiding boiler troubles while not losing in hauling ability.

Attention is directed to the difference between compounding and superheating in the comparison of advantages and economies for locomotives vs. stationary and marine engines. While compounding in locomotives is harassed by so many limitations in locomotive operation that it has had to be developed through much tribulation into its present success, superheating has to be altered and specialized for the locomotive only in detail matters, due chiefly to the type of boiler which has become universal for locomotives. It is said, however, that these detail matters in two of the well-known types of superheaters "give troubles enough to condemn superheaters finally, if we had no other types to go to," in the words of a prominent Chicago railway mechanical engineer at last June's convention of the American Railway Master Mechanics' Association. Joints prone to leak, and yet extremely difficult of access, empty steam tubes burned, smoke tubes clogged, neglected dampers, improper lubrication—are all being overcome. To quote from the Canadian Pacific experience, as narrated this summer before the American Society of Mechanical Engineers:

> The writer's experience with locomotives using superheated steam has not been free from vexations and annoying troubles, but it has on the whole been exceedingly satisfactory. * * * * The troubles encountered are being overcome as experience develops their cause and the saving obtained is apparent in the reduction of the amount of coal used per ton-mile on various divisions of the road as superheater locomotives are introduced. The additional capacity of the engines and the reduction of the work required of the fireman, enabling trains to be handled better, and the development of an engine which *in extremely cold weather* can be as easily maintained as a simple engine with an economy equal or superior to that of a compound is an important advantage to any road working in northern latitudes. * * * * So far as can be seen at present there is no valid reason for discontinuing the application of superheaters, and the writer expects that a considerable increase in the number in use will take place in the next few years.

It may be said, as in the book under review, that the principal problem, after the fundamental one that the superheater must actually and efficiently superheat, is to "make the apparatus convenient for application without detracting from the steam generative efficiency of the boiler and without interfering with tube cleaning and repairing," to which may be added that it must have a confirmed tendency to remain tight after reasonably careful putting up. If a repair should be necessary, the particular part needing it must be capable of immediate location by the eye, and of easy and quick repair without disturbing the entire apparatus and without appreciably withdrawing the locomotive from service. The automatic damper, to protect the superheater when empty of steam, is also an important feature. A minimum of joints and complication will also commend a successful design to Americans.

As to economical results, the Canadian Pacific has now so large a number of superheaters that they must surely be standing on their own merits in general service. A few locomotives, fitted with a device known to be favored by the officials, might be nursed by the engine crews and hence show an unreal fuel economy. The Canadian saving on monthly performance sheets, not in special tests, is 10% to 15% in freight service and 15% to 20% in passenger, with no decrease in monthly mileage and an unimportant, because insignificant, additional cost of maintenance. As one American official this summer said to the writer: "It needs interest and attention, not expense." Prussian, Swedish and Belgian performances appear by the figures to be twice as favorable as the preceding, some of them, moreover, when in competition with compounds.

The reader who wishes to go more deeply into this subject should possess himself of a copy of the New York Railroad Club Proceedings for April 20, 1906, wherein a paper was presented by Mr. Vaughan, formerly mechanical superintendent and now assistant to the vice-president of the Canadian Pacific. The discussion and contributed information were especially valuable. In the 1905 Proceedings of the American Railway Master Mechanics' Association Mr. Vaughan went into a highly theoretical as well as practical treatment of the subject. The most recent discussions may be found in the Transactions of the American Society of Mechanical Engineers for May, 1907, and in the Master Mechanics' Association for June, 1907. The best historical account of superheating for locomotives has been given by Mr. F. J. Cole before the Central Railway Club of Buffalo, N. Y., reprinted in the Railroad Gazette for Feb. 8, 1907, page 181.

It is to be regretted that the author seems not to have fully appreciated the rapidly-growing economic and operating importance of superheating for locomotives, and hence did not go thoroughly into the theory and practice on the subject. There are abundant signs of a possible dropping of the successful compound for the more successful superheater locomotive. This is an interesting double development, coming as it does at a time when heavy electric traction puts in its claim for economies in competition with steam. The most recent book, also from an English viewpoint, upon "Electric Railway Engineering," by Parshall and Hobart, says:

> It is to be steadily borne in mind that the steam locomotive has demonstrated itself to be the most efficient self-contained machine, considering its varying functions, that the engineer has yet devised. Hence every appliance entering into the electric traction installation must compare from every point of view, as regards efficiency, with this most highly developed and perfect mechanism.

Mallet slow and heavy engines, and compound or superheater lighter balanced engines, may everywhere set a new steam standard for the electrics. The former was set by Mr. Muhlfeld, of the Baltimore & Ohio, in his epoch-making paper on "Large Electric and Steam Locomotives," before the New York Railroad Club, Feb. 16, 1906, giving results with his Mallet.

Mr. Gairns gives us probably the best book on compound locomotives which has appeared since Barnes-Woods in 1892. In the preface one reads: "The author has not devoted much space to theoretical and highly technical aspects," and credit is given to the American book as being of a character which can never become quite out of date in these respects. Those who have supposed themselves well acquainted with compound systems will receive a revelation. The book is good to read, with its convenient size, its excellent line drawings, though without dimensions, and pages free from padding by needless tables or locomotive sizes. The use of heavy, black-faced type headings for the discussion of each system of compounding or superheating, as subdivisions within chapters, catches the eye quickly. Occasionally a series of objects or reasons are outlined at the beginning of a chapter or section like a lawyer's "brief," afterward to be discussed or proved. It would be well to have more of that in technical writings. Conclusions might oftener be placed first, for the busy man or to enable the reader to follow for himself the bearing of the author's subsequent argument or train of thought.

In common with much engineering writing, this author refrains from adverse criticism of particular types or systems. Some objections are enumerated to general types as two-cylinder and tandems, and in three instances to an English design, an Italian cylinder, and a French articulated; but some of the most notoriously, though sometimes numerously built, unfortunate designs get no word of criticism. The troubles which railways experience with lack of flexibility for varied service, expected economies negatived into actual waste, and repeated breakdowns causing annoying train detentions or excessive time in the shops, which have in practice been emphatic in particular designs, are unknown to the author's pen, though undoubtedly familiar to his experience or in a measure accessible to his inquiries. Frankness in writing need not bear the stigma of fault-finding or "knocking" if praise be as liberally distributed where merited as its opposite, especially if the latter be given in a kindly spirit of help for future designers and with a conspicuous fairness which can disarm even the inventor and promoter.

As a whole, the book is worthy of a place upon the railway engineer's and locomotive designer's shelves. It will be a help to the understanding of both compounding and superheating, and will aid in preparing the way to a choice or design of those types of locomotives best suited for the region and traffic to be handled.

Of very convenient size, in type clear, yet not wasteful of space, and packed full of value, would be the judgment on Mr. Sinclair's latest book. At the very outset, however, it may be ventured that a table of contents would help the "ambitious" and, perhaps, busy reader to find just that chapter or section he may most need, and upon which he may desire to bend his energies in study. The index is available, but a table of contents is also needed. It may be hoped that a later edition will at least collect as such an aid the existing heads of sections, as Firemen's Examinations, Compound Locomotives, Air Brakes, and Lubrication; and such sub-divisions as Accidents to Valve Motion, to Running Gear, etc.

The book first treats of the many points concerned in good engine-crew work, arranged in the order of increasing difficulty and skill required, as for examination for proficiency of firemen of one, two or three years' service. In these questions or "catechism" are included many engine difficulties and breakdowns and their handling, but somewhat less extensive than in the author's earlier book (1890), "Locomotive Engine Running and Management." It might seem strange to the public, knowing the author and his railway periodical so well, that in his chapter on

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Valve Gears no mention is made of the Walschaert, that well-nigh universal European gear which has taken such a hold upon American practice.

Then comes a chapter on Compound Locomotives, but here again is no word on tandems, four-cylinder balanced or Mallet articulated, the last two being types which are looming up for speedy engines or extremely powerful freights, both, by reason of their design, inherently gentle upon the severely-tried rail. Furthermore, there is no word on the simple, very economical and increasingly trustworthy superheated-steam locomotives, which are making the rapid strides indicated in the opening paragraph of the preceding review on Superheating.

The chapter on Air Brakes, of course, includes the high-speed, but not the still more recent Westinghouse "ET" engine and tender brake equipment. Following in order come Master Car Builders' Air-Brake and Train Signal Instructions, Sight-Feed Lubricators, Electric Headlight, the American Railway Association "Train Rules," and Oil-Burning Locomotives.

The book is based on the Examination of Engineers and Firemen, as conducted by a leading railroad, questions developed by the Traveling Engineers' Association and since extended. Its different chapters should be of value for each class of employee on trains, and may well also be studied with care by young men expecting to enter Railroading in the mechanical or operating departments.

Mr. Wallace's book agrees with its title-description in that the questions with answers thereto were asked through a firemen's magazine. There has been no attempt to arrange them in any systematic order, with the result that not only is the same question asked and answered in several different places, usually in fair duplicate, but also that the reader who desires to understand any one subject, as the sight-feed lubricator, must laboriously pick out and read questions and answers No. 1, 2, 20, 35 to 41, 50, 62, 65, 74, 85, 105, 163, 241, 299, 335. A question on Lining Up a Stationary Engine is sandwiched in between an Indirect Motion Locomotive and a Sight-Feed Locomotive Lubricator; or Scale in a Stationary Boiler between a Locomotive By-Pass Valve and Keying Side Rods. Even the index must be used with care to cover one subject, for Question 164 is there found under Valves, and 249 under Compounds, though both begin: "How would you test for a valve blow in a Vauclain four-cylinder compound?" It is to be hoped that the reader sees the reference to Question 164 first, for the author explains the matter in 2½ pages, but in the answer to Question 249 states that "The detection and location of blows in any engine is not always an easy thing to do at all times, and more difficult on a compound, and mechanical officers should not expect too much from enginemen. For details covering full answers see—another book for sale bearing the same surname as the copyrighter of this book. Question 168 states that cylinder centers and driving axles ought to be always on a straight line. Question 178, regarding the load on a "one-inch staybolt", is answered by giving it an effective area of .7854 sq. in. at the root of the thread, which is actually the full cross-sectional area of a 1-in. unthreaded rod.

In a book bearing the imprint of 1907, nothing is said about the very large number of Walschaert valve gears in use in this country, though that type shows in the large illustrated inset of the 2-6-2 balanced compound. The balanced compound is mentioned sufficiently to form an advertisement for another 15-cent pamphlet on that subject, also by the same publishers as in 249 above. With superheaters increasing so rapidly in numbers, this book allots two-thirds of a page to the subject. Mallet articulated compounds for heavy freight service get eleven lines of description. Possibly all of these omissions or too brief allusions were due to this book being a reprint from questions asked and answered not recently.

Questions 129 and 148 illustrate the quibbles of duplicate questions with perhaps enough faint mental reservation to elicit opposite answers.

The book undoubtedly will be of interest in the gossip of the roundhouse, and much indeed of value can be dug out of its pages. All of us who have shared in those informal discussions around and about the steel horse know their attraction, though realizing their casual, undecisive or disconnected nature. This collection might, with rearrangement, excision and addition, serve a far more useful purpose in systematic education of the men whose very business is system to a degree, and who deserve and are always anxious to learn from those best qualified to teach them the principles of mechanical science related to their duties.

For Sea-Going Engineers.

Reviewed by D. W. TAYLOR.*

PRACTICAL ADVICE FOR MARINE ENGINEERS.—By Charles W. Roberts, Author of "Drawing and Designing for Marine Engineers," etc. Second Edition, thoroughly revised and rewritten. London, England: Whittaker & Co. Cloth; 5 × 7½ ins.; pp. 206; 82 illustrations, mostly in the text. $1.

It is seldom that one finds a technical book whose nature is indicated so clearly by its title and whose contents are restricted so firmly to the ground which the author has set himself to cover as in the case of this little treatise, containing 206 pages and 82 figures. It does not cover the whole field of marine engineering. It is intended for the use of the sea-going engineer and, in the words of the author, "to form a concise and handy guide to some of the more important matters that demand the attention of marine engineers, and is published at such a cheap price as to make it easily procurable by all."

The author treats, first, of the marine engineer in general. After a few remarks on his social position he gives the usual division of watches and the assignment of more important duties to the various engineers aboard ship, touching upon their relations to one another and to the deck force. He follows with brief discussions of and advice concerning the main boiler plant, the donkey boiler, the engines proper, the line shafting, and, finally, the propeller. While the volume is small, there is no padding. The author wastes few words and, writing as he does for persons already acquainted with his subject, does not consider it necessary to define every term used, or describe every fitting referred to. For instance, on page 124, there are suggestions in connection with the use of leads in the adjustment of main bearings without any attempt to define or describe leads themselves.

Besides the propelling machinery proper, auxiliary machinery and appliances directly connected with it, such as feed-pumps, hydrokineters, air pumps, feed water heaters, and evaporators, are discussed by the author, who describes well-known patent fittings of this nature, which he has presumably handled at sea. Other auxiliary machinery, however, such as electrical appliances, refrigerating machinery and oil engines, are not covered, and even deck winches are referred to only when enumerating the duties of the various engineers.

There are more typographical errors than should be found in a second edition, and besides British expressions which seem strange to American eyes, such as "rimering" instead of "reaming," there are a few words used which seem rather abnormal. Thus, on page 26, the author speaks of restoring a collapsed furnace to its original "circularity," and, on page 29, of "oxidisation." On page 50, the author, in describing a diagram, refers to spaces marked R R, which in the diagram are actually marked A A. On page 188, a reference to Fig. 62 should evidently be to Fig. 78. On page 174 there is a puzzling typographical error: instead of "cement wash is" we have "cement was his."

While the author covers a limited field and appeals primarily to a single class, the field is covered in an instructive and interesting manner. The book should be of decided value to the young sea-going engineer.

*Naval Constructor, U. S. N., U. S. Navy Yard, Washington, D. C.

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PREFACE
TO THE FIFTH EDITION

In preparing the Fifth Edition of this book, the whole work has been thoroughly revised with the view of bringing the information contained as much as possible up to date. The newest theories proposed for the design of masonry dams have been mentioned in the Introduction. The chapter on the construction of masonry dams has been entirely rewritten. Descriptions of all important dams built or in course of construction, of which the author could find any record, have been given, and in the cases of the New Croton Dam, the highest masonry dam thus far built, and of other noteworthy reservoir walls, the construction has been described with considerable detail. The text has been illustrated by numerous plates and figures.

Among the new matter added to the book are descriptions of steel and concrete-steel dams, high earth dams, Stoney sluice-gates, and rolling dams. In the present edition the work contains 93 pages of reading-matter, 39 plates, and 45 figures more than appeared in the Fourth Edition.

The information given has been gathered from many sources, partly from printed records and partly by correspondence. The author wishes to acknowledge here his indebtedness to the many engineers who have assisted him by supplying desired data about dams, and he has endeavored to give due credit for such assistance in the text of the book.

The preparation of this edition has involved much work, and the author hopes that the many hours spent on the revision may have added to the practical value of the book.

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Water-Works Design, Construction and Operation.

Reviewed by DABNEY H. MAURY,* M. Am. Soc. C. E.

WATER-WORKS MANAGEMENT AND MAINTENANCE.—By Winfred D. Hubbard, Assoc. M. Am. Soc. C. E., and Wynkoop Kiersted, M. Am. Soc. C. E., Consulting Engineer. New York: John Wiley & Sons. London, England: Chapman & Hall, Ltd. Cloth; 5¾ × 9 ins.; pp. 429; 114 illustrations, mostly in the text. $4.

The title of this important book is somewhat misleading, as less than half the volume is devoted to the management and maintenance of water-works. Part I., which fills 217 out of a total of 419 pages, deals with the securing of water supplies from various sources, and the selection and installation of pumps; Part II., 167 pages, discusses more particularly the various features of management and maintenance, but also necessarily contains much that relates to construction work; and Part III., 35 pages, treats from various points of view the subjects of Franchise, Water Rates and Depreciation. In their introduction to the work the authors have apparently anticipated the foregoing criticism by explaining that the problems relating to the maintenance and operation of a system of water-works often depend so largely for their solution upon the details of the original design that it was deemed advisable to outline to some extent in Part I. the various methods by which a supply is secured.

The first three Chapters of Part I., on Ground Water Supply, River Water Supply and Pumping Engines, bear Mr. Kiersted's initials; the fourth chapter of Part I., and the 14 chapters which make up Part II., are by Mr. Hubbard; while Part III. is to be credited to Mr. Kiersted.

The chapter on Ground Water Supply sets forth the principles governing the flow of water through sands and gravels, and is a valuable contribution to the literature on this subject. It is illustrated somewhat copiously by examples from the work of the author in the Middle West; but the illustrations are pertinent, and, in fact, form the basis of some of the formulas given for calculating slopes and yield of underground supplies. It is to be regretted that these formulas are not followed by other typical examples, as the average water-works superintendent may find them, as enunciated, rather difficult to understand and to apply to his practical needs.

The treatment of strainers, and of drop pipes, suction pipes, and siphon pipes, brings out some very useful and hitherto often-neglected ideas and suggestions.

Considerable space is given to a discussion of Iron Removal plants, this part of the work being largely made up of cuts and descriptions of some small, though interesting, plants installed by the author. In the chapter on River Water Supply the subject matter is treated under the heads of Settling Basins, Circulation, Coagulation, Winter Treatment, and Filtration. While there is much of practical interest and value in this chapter, most of the cuts and examples relate to the treatment of the waters of the Missouri and Mississippi, or to plants designed by the author.

The chapter on Pumping Engines, after presenting diagrams of coal consumption and duty, describes in a general way the various types of pumps, and the considerations which should govern the purchaser in his selection. The chapter on Impounded Supplies treats briefly of color, and microorganisms, rainfall, run-off, and storage. A number of tables and diagrams are presented, most of which give the results of the experience of the Metropolitan Water and Sewerage Board, Boston.

Part II. begins with a chapter on Plans and Records, which contains a number of useful, though not especially novel, suggestions, based on current practice in well-managed works, for making and maintaining plants and records. The next chapter treats of extensions, and contains general directions for this work, most of which are embodied in the usual specifications for pipe-laying. The tables of General Dimensions of Cast Iron Pipe and Specials are reprinted from the Specifications published by the New England Water-Works Association. Cross sections of typical hydrants and valves and valve boxes are also given; as well as diagrams and data for quick approximate estimates of cost per foot for labor and materials of pipe of various sizes and weights.

In Chapter III., on Service Connections, a resumé of usual good practice in laying service pipes is followed by an extract from a paper by Mr. F. F. Forbes on lining wrought iron service pipes with cement. The possibility of lead poisoning from lead services in certain waters is discussed; and data in regard to cost of service pipes, and a diagram showing friction losses in pipes of various sizes, are also presented. Chapter IV., on Meters, opens with descriptions and cuts of the various commercial types of meters. Data relating to the cost of meters, and of their setting, maintenance, reading and inspection, under various conditions, complete this chapter.

In Chapter V., on the Care of Appurtenances, after a few brief notes on care of pumping plants and stand-pipes, there are presented some useful hints as to the care of hydrants, including a strong and timely caution against allowing them to be used indiscriminately by contractors for street sprinkling, or by other unskilled or irresponsible parties. Data in regard to methods and cost of cleaning mains, and of thawing frozen service pipes are also included. In the next chapter, under the head of Alterations and Repairs, the author describes methods of tapping, repairing and lowering mains; repairing or renewing stop-cocks without loss of water; and the lining of reservoirs with asphalt or other waterproof coating.

Chapter VII., on Maintenance of Quality, deals with the care of impounding and storage reservoirs, including protection against pollution; and the drainage of swamps. The growth of microorganisms in reservoirs, and their removal, are briefly touched upon, with references to the work of Dr. Whipple and of Dr. Moore. After a few suggestions as to the flushing of mains and cleaning of reservoirs, the chapter closes with a short description of the methods of chemical and bacteriological examination of water supplies, and a general interpretation of their results.

Under the head of Water Wastes, Chapter VIII. gives statistics of water consumption in various cities and towns, with numerous quotations from the valuable papers of Mr. Dexter Brackett on this subject; also some timely allusions to the waste of water by municipalities in schools and other public buildings, and by automatic flush tanks. Under the sub-title "Investigation of Wastes," various commercial measuring devices, including the Venturi Meter, Deacon Meter, and Pitometer are described. Under Waste Prevention, the use of service meters, house-to-house inspection, and the Deacon System are discussed. The author prefers meters to house-to-house inspection. Mr. J. R. Freeman's well-known diagram showing the effect of use of meters on consumption of water in various cities is reproduced; as well as Mr. George I. Bailey's table giving summaries of population, water consumption and receipts, in 134 cities of over 25,000 inhabitants, the results being arranged according to percentage of taps metered. The author presents forcible, if not, new, arguments in favor of metering.

Chapter IX., on Electrolysis, contains a general discussion of the subject, with references to papers by Prof. D. C. Jackson, Mr. D. H. Maury and Mr. A. B. Herrick. While the author is undoubtedly sound in his conclusion that the only practical method of preventing electrolytic injury is to keep the street railway current out of the ground, as is successfully accomplished by the double trolley, he weakens this statement later by referring to a number of wholly unpractical suggestions for curing the trouble: such as laying cast iron mains with bell ends in the direction of current flow, avoiding the location of tracks over and parallel to water mains; enclosing service pipes in asphalt, rubber hose, or the like; and other equally absurd expedients which have been from time to time suggested by street railway engineers, as measures to be adopted by water departments to protect their pipes against injury caused by the railways. Even if any of these suggestions had value, none of them could apply to pipes already laid. The pipes are in the ground; the current is on them; and it can be removed by the street railways that put it there, and by them alone.

Much useful information is condensed in Chapter X., on Fire Protection, which contains quotations and diagrams from Messrs. Freeman, Kuichling, Shedd, Fanning and Metcalf, and a number of handy diagrams relating to pressures, nozzle discharges, and friction in hose, and in old and new cast iron pipe.

Chapter XI., on Accounts, gives about five pages to brief suggestions for a system of accounts very similar to those already in use in most water-works, and calls for little comment. Chapter XII., on Financial Management, is devoted to a discussion of the method of fixing proper rates, more especially in connection with meter services. The author in this chapter shows a broad and comprehensive grasp of the principles which should govern the fixing of equitable rates, and his arguments and conclusions merit the careful consideration of the many water departments whose rates have been fixed haphazard. The next chapter, on Rules and Regulations, is practically a resumé of current practice.

Chapter XIV., under Annual Reports, includes the familiar standard form recommended for such reports by the New England Water-Works Association.

Part III. of the book is devoted to a somewhat lengthy dissertation on the subjects of Franchise, Water Rates and Depreciation. Under the first heading the author, after giving an outline of the origin of water-works franchises, leads up to the point where the water-works plant is about to be purchased by the city, and presents arguments bearing upon the proper methods of valuation, from the respective standpoints of the owner and of the purchaser. Under the heading of Water Rates appear some tables of friction losses in various sorts of hose, which form part of an argument in favor of a change in the usual ordinance provisions for tests of fire service; and also some tables showing income from and cost of operation of municipal and private water-works, taken from the Fourteenth Annual Report of the Commissioner of Labor. The last few pages of the book treat of various methods of estimating depreciation, more particularly in connection with appraisals.

Considered as a whole, this book may be likened to Mr. J. T. Fanning's much earlier "Water Sup-

*Consulting Engineer, Engineer Peoria Water Co., Peoria, Ill.

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ply Engineering," revised and brought up to date. It attempts, however, to cover so wide a field that it can say comparatively little, in this day of specialization, on any one topic. And it is not to be expected that it will become, as did Mr. Fanning's work, a standard book of reference. But along with a reproduction of many facts already well known to every competent water-works man, and many citations from papers which have already been frequently published, there are a great many useful and practical suggestions, nearly all of which are in the line of good modern practice. All of these make the work a valuable addition to water-works literature.

An Unconventional Treatment of Mechanics.

THE ELEMENTS OF MECHANICS.—A Text-Book for Colleges and Technical Schools. By W. S. Franklin and Barry MacNutt. New York: The Macmillan Co. London, England: Macmillan & Co., Ltd. Cloth; 5½ × 8¼ ins.; pp. 283; 180 text illustrations and 1 plate. $1.50, net.

Here is a book which while dealing with a well-exploited subject yet is marked by strongly unconventional features, and that too without departing from proper scholastic standards of excellence in its details. The unconventionalities indeed give the book its stamp, and mention of them will form a sufficient review for the reader's information. Let us premise that the book is intended as a "text-book for colleges and technical schools," presumably for the use of engineering students, that it is written by two teachers of physics, and that in its mathematics, language, typography and illustrations it is quite up to standard.

The first unconventional thing about the book is the inclusion of a large amount of text-matter not concerned with Pure Mechanics at all. Text-books on mechanics, particularly elementary ones, generally restrict themselves to the study of forces and motions. This subject is large enough to fill a substantial book, and it *must* be well taught to the student if he is to get the proper benefit out of his subsequent studies. For this reason a book on Mechanics is almost necessarily confined to Pure Mechanics in this sense. "Applied" branches, such as the study of stresses and strains, fluid pressures and motions, thermal conduction and heat actions, etc., are rightly put by themselves, under separate titles and in separate books. Of the present work about one-third is devoted to subjects of this kind (Elasticity, Hydrostatics, Hydraulics). They are not treated at all comprehensively, but rather so fragmentarily as to be utterly insufficient for the needs of engineering students. It may be argued, perhaps, that, by presenting various applications of the principles established in the chapters on pure mechanics, they give practice in the application and shed more light on the meaning of these principles. This is by no means the case, however, as is shown on the one hand by the fact that the problems appended to the earlier chapters do not deal with the subjects taken up in the later chapters criticized, and on the other hand by the fact that these later chapters are essentially concerned with the consequences resulting from specific properties of certain materials, while the study of Mechanics per se has nothing to do with materials but only with forces and with the action of forces on bodies generically speaking.

One feature of this inclusion of extraneous matter claims separate mention. The first two chapters following the introduction are devoted to: Measurement of Length, Angle, Mass and Time; and Physical Arithmetic. These appear to be inserted on the theory that the subsequent work is founded upon them either in logic or in pedagogical procedure. We find difficulty in perceiving any such relation. To our view the dividing engine, the planimeter, the chronograph and the vernier have no more to do with the science of forces and force-actions than has the picture of International Prototype Kilogram No. 20, which forms the frontispiece. The ideas expounded under the title Physical Arithmetic are perhaps more appropriate to the book, but it happens that those which are not so elementary as to be unnecessary are not made use of subsequently: the hodograph, for instance.

Curiously enough the only explicit mention of that fundamental principle, the composition and resolution of concurrent forces, occurs in this prefixed chapter. It is stated that vectors are added geometrically, that forces are vectors, and that (as an illustration) the resultant of two forces acting at a point in different directions is represented by the diagonal of a parallelogram, etc. Later on, in the short chapter on Statics, this statement is made use of, without more being said. There is no attempt to found this primary principle or process on a demonstration or a plausible line of reasoning. It is put into the student's mind (if indeed it ever gets there) as a mere piece of formalism. Surely no more devitalizing step could have been taken by the authors! All interest in or understanding of force-systems is destroyed before it is created.

There is much more ex cathedra statement in the book, so much indeed that, in connection with the hurried or general treatment and "suggestive" method prominent at many points, it tempts one to attribute to the authors an impressionist view of their subject. This of course would be wrong, as they abundantly exhibit sharp, orthodox thinking; yet their book would, we fear, make the student something of an impressionist in Mechanics—a dangerous state for an engineering student.

A further unconventionality about the book under review, the last to be noted here, is its introductory chapter. This is an essay divided into the three headings: The Laws of Motion, Physical Measurement, and The Study of Physics. It is apparently designed to furnish

> a point of view from which the student must inevitably proceed to a minute consideration of the bare principles of the science.

If it be possible to devise a point of view which, when furnished to a student, compels him inevitably to proceed to thorough study of his subject, it will prove an immensely valuable thing for teachers of Mechanics. We do not believe this to be possible. Truth compels us to say, however, that a student who is able to read through this Introduction with conscientious attention will not be apt to give trouble subsequently from a tendency to insufficiently minute consideration. The fact is, this introduction is long, complicated and, in parts, what the unwashed call "highfalutin." We suspect it to be either very lofty or else absurdly out of place in the present work, and we are inclined to take the view that it is very lofty, because of the select language employed; see for example the specimen of alliteration on p. 4:

> irresistible sweeps of destruction in fire and flood, and in calamitous crash of collision and collapse where all things commingle in one dread fluid confusion.

But it is questionable whether a lofty introduction is useful for the mere purposes of a scientific text-book, one whose method should be, according to the authors' quotation from Bacon,

> continually to dwell among things soberly.

A sober-dwelling person should have edited this part of the book. Such a one would also have eliminated, we think, several references to "the senior author," whose identity is defined only by the information that he is the one who wrote the Introduction.

INSTRUCTIONS TO INSPECTORS ON REINFORCED CONCRETE CONSTRUCTION AND CONCRETE DATA.—By Geo. P. Carver. Beverly, Mass.: Payson Publishing Co. Stiff paper; 4 × 6½ ins.; pp. 80; illustrated.

The art of building in concrete is of recent development and has not as yet reached that stage where it is capable of being completely codified. There are, however, certain well-established rules for such construction, and in the effort to spread them there has of late appeared several handbooks for the concrete worker, all of which have titles somewhat similar to that noted above, and all of which contain more or less of the same material. The information here given is of little value to the trained concrete man. For the amateur and for those who think the experience gained in building a concrete walk warrants them in attempting a six-story building the instructions will prove a considerable help. It is to be regretted that the author did not carry out in full the excellent plan of crediting to periodical publications certain of the cuts which they provided for the work.

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Wealth and Socialism.

THE LIMIT OF WEALTH.—By Alfred L. Hutchinson. New York: The Macmillan Co. London, England: Macmillan & Co., Ltd. Cloth; 5 × 7¾ ins.; pp. 285. $1.25, net.

SOCIALISM.—By W. H. Mallock, M. A., of England. A Series of Lectures Delivered at Columbia University, Harvard University, etc., under the Auspices of the National Civic Federation, February, 1907. New York: The National Civic Federation. Paper; 5 × 7 ins.; pp. 138.

Each of these volumes is directed against Socialism. The first seeks to combat it by placing a limit on the amount of wealth a man may dispose of, either during life or at death; the second is a critical review of the tenets of Socialism, as those tenets are understood by the author. Mr. Hutchinson's book is constructive. It goes far towards laying out an entirely new scheme of government, while at the same time reconstructing society and reforming the church. One would scarcely think of it as anti-socialistic did not the author so designate it. Mr. Mallock's book consists chiefly of destructive criticism. It has more dignity and literary finish than Mr. Hutchinson's "Limit of Wealth," but to most people will be far less interesting. We recommend both as worthy of attention.

To make his plan seem reasonable and real Mr. Hutchinson throws his book into the form of a brief abstract of a voluminous report, made only 37 years hence, on why the United States had so far surpassed all the other nations of the world in wealth and industry, and notably in the general welfare of its people. The report is supposed to be made at the instance of the rulers of seven great European and Asiatic nations. Right here it may be said that the nearness of the date assumed makes the book suffer, as compared with other Utopian efforts, through lack of perspective.

Mr. Hutchinson's plan of limiting wealth is really a plan for distributing it, while at the same time putting no limit on its acquisition and enjoyment. Under the plan, no man could dispose of more than $1,000,000 at death, and that only in restricted ways; and to make sure that wealth is available for distribution at death for the benefit of the nation or its people, a strict limit is put on giving it away during life.

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There is no government ownership of railways or the like. In fact, even the Post-Office is farmed out to a private company. Competition by public service companies is feature, even to the extent of encouraging two telephone systems. Coast defenses and the like are to be developed ad infinitum, so as to make foreign attack hopeless. The protective tariff is to be held sacred, though revised. Wonderful reforms in various industries, and particularly in farming and rural life, are to be effected, largely by means of a mysterious but undescribed electric battery. Schools, jails, courts, churches and other institutions are to be reformed wholesale, and poor houses are to be abolished.

The book contains some crudities of plan and detail and an inexcusable number of grammatical or typographical errors. In so far as it proposes to distribute huge incomes at death by taxation, its plan probably stands more chance of being carried out than those of most Utopian books.

Of Mr. Mallock's lectures we can only say, further, that they present strong arguments against cutting off Capital without a cent and giving all the product of industry to Labor—pro rata, man and man, hour and hour alike—and he also shows that those who work with their heads, only, well deserve to be considered wealth producers.

REPORT ON THE RAILWAYS IN INDIA.—Pub. Doc.; The Railway Board, Simla, India. Paper; 8¼ × 13 ins.; pp. 283; maps.

This is the first annual report of the new Railway Board, and covers the calendar year 1906. It consists mainly of statistics, but includes also the rules adopted in regard to the design and inspection of signaling and interlocking plants.

Copper Mines.

THE COPPER MINES OF THE WORLD.—By Walter Harvey Weed, M. Am. Inst. M. E., M. Inst. M. E. New York and London: Hill Publishing Co. Cloth; 6 × 9¼ ins.; pp. 375; 150 illustrations, mostly in the text. $4.

With copper's precedence among the non-precious metals, owing to the enormous demand for it in the electrical industries and the fact that it is the basis of all brass and bronze alloys, this book, written and compiled by one so well fitted both through his travels and his study and association with the U. S. Geological Survey as is Mr. Weed, will fill an important niche in the libraries of mining men, investors, and students, and of those as well who are interested in the metal from the industrial point of view only.

The work does not attempt to treat various properties described from the viewpoint of their financial merit; nor does it lead the reader into the deeper technicalities of physical chemistry or metallurgy. On the contrary it is, so to speak, a bird's-eye view of the copper world, so presented as to answer such questions as: (1) Where are the deposits found? (2) What is the nature of the ore and its amenability to treatment? (3) How much of it is there? (4) What is the geologic occurrence—i. e., what are its structural, mineralogical and chemical relations? (5) What is the bearing of the observed and recorded facts on the probability of richness and continuity in depth? (6) What is the genesis of the deposit, and its bearing on the present and probable future production?

From the geological standpoint, the author has handled the subject with an undeniable mastery and comprehensiveness. With his equipment of experience in that direction this is by no means surprising. The work is, in part, "confessedly a compilation;" but, in spite of the author's wide personal contact and experience, the very nature of such a treatise precludes absolute adherence to first-hand presentation.

The work consists of two main divisions: Part I., devoted to the geology of copper—the distribution of deposits, statistics of production, a chapter on the mineralogy of the metal, etc., seven chapters in all; Part II., devoted to descriptions of the world's principal copper mines, ten chapters.

It is from the concrete facts recorded of these existing workings that the geological and metallurgical deductions of Part I. are drawn. Only the most important mines are described, including those producing at present and others that are noteworthy because of their past history or because a study of them may have a bearing on the judgment of more recently discovered deposits. The copper mines of Japan—not widely known as a copper-producing country, and yet containing 38 of the 250 greatest copper mines of the world—occupy an entire chapter. The last and longest chapter of the book covers the copper mines of our own country, by states.

A possible minor criticism is that, in Chapter II., on "Production," some of the world's-production tables and diagrams are in terms of metric tons, others in terms of long tons, while United States statistics are given in pounds. This disparity in units does not facilitate off-hand comparisons by the reader.

SPIRALS FOR STREET RAILWAY CURVES, and Easement Curves for Street Railway Branch-Offs.—(For private distribution). Steelton, Pa.: Pennsylvania Steel Co. Leather; 4¼ × 7 ins.; pp. 80 + 16 of advertising; illustrated.

While this book is issued by the company for the use of its customers, it is an engineering work, the only advertising matter consisting of 16 pages of views and particulars of specialties in switches, frogs and switchstands. The system of spirals described is stated to have been in use for several years with satisfactory results. The first few pages are devoted to problems in the selection and forms of spirals, and four pages

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to the forms of flanges for wheels of electric cars. The greater part of the book is devoted to tables for curve spirals, switch easements, tie-rod spacing and middle ordinates for 10-ft. chords. At the back of the book are several pages of section-paper for memoranda.

Coal Mining.

THE PRINCIPLES AND PRACTICE OF COAL MINING.—By James Tonge, M. Inst. M. E., F. G. S. London, England: Macmillan & Co., Ltd. New York: The Macmillan Co. Cloth; 4¾ × 7⅛ ins.; pp. 363; 203 illustrations in the text. 5s., net; American price, $1.60, net.

The author of this book evidently had in mind, in its preparation, meeting a demand for a compact, comprehensive, and not too technical treatise covering the entire field of coal production. It is adapted to use as a lighter text-book for students intending to specialize in mining engineering, and is so written as to be equally well adapted to the needs of the practical miner who may wish to qualify for higher and more responsible positions in the coal-mining industry.

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A chapter on preparation of coal for the market, and one on mining accidents and diseases to which miners are subject, and legislation on mine-labor legislation, close the work.

The illustrations, both photographic and diagrammatic, are comprehensive, and serve well to illuminate the descriptive matter. At the end of each chapter is a series of questions bearing upon it, as an aid to fixing the subject matter thereof in the memory of the student.

GUIDE DU MONTEUR (The Erection of Machinery).—By Jules Meriot, Mechanical Engineer, Paris; Librairie Polytechnique (Ch. Beranger, Editeur), 15 Rue des Saints-Peres. Cloth; 6½ × 9¾ ins.; pp. 283; 306 figures in the text. 9 francs. (No index.)

This book is devoted to the methods employed in the erection of steam machinery, with pipe systems, belting and other appliances. The subject is treated in eight chapters. Chapter I. deals with the measuring and testing instruments employed; plumb bobs, spirit levels, water levels, squares, etc. Chapter II., which covers but five pages, deals with the elementary principles of geometry. Chapter III. takes up the question of foundations, including the arrangement of anchor bolts. It briefly discusses the isolation of the machine from the foundation or of the foundation from the earth, in order to avoid the transmission of vibrations. These three chapters are of a preliminary character, and cover only 36 pages.

Chapter IV. (61 pages) takes up the subject of pipe joints, including brazed, sleeve, flanged, screwed, bolted and bell-and-spigot joints. The support of pipe lines by hangers and rollers, and the attachment of valves, are also dealt with, as well as machines for cutting, threading and expanding pipes. Expansion joints are only mentioned, and none are illustrated or described, although a U-pipe is shown which allows for expansion and contraction movements in pipe line. Chapter V. (54 pages) deals with the erection, alinement and adjustment of a steam engine, with its cylinders, shaft, bearings, cranks, crosshead, etc. Chapter VI. discusses the detection and correction of defects in erection, as indicated by shocks or vibration when machines are at work. This includes such work as testing the correct position of cranks, bearings, etc.

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The book is largely elementary, treating principally of a simple slide-valve engine. It is intended for the use of students at technical institutions, machinists, shop foremen and superintendents. There is a list of contents for each chapter, but the book has no index. It is printed in large, clear type and the illustrations include simple line drawings, with cuts of instruments and appliances.

Publications Received.

AMERICAN INSTITUTE OF ARCHITECTS.—Proceedings of the 40th Annual Convention, and of the Celebration of the 50th Anniversary of Its Foundation. Held in The Octagon, Dec. 29, 1906, and at the New Willard Hotel, Washington, D. C., Jan. 7-9, 1907. Washington, D. C.: The Institute (Glenn Brown, Secy.). Paper; 6¾ × 9¾ ins.; pp. 216; one plate.

ATLAS OF NEW YORK CITY AND THE METROPOLITAN DISTRICT.—New York: The Audit Co. of New York. Paper; 10¼ × 13¼ ins.; pp. 16.

BOARD OF HEALTH OF THE STATE OF MICHIGAN.—Annual Report of the Secretary for the Fiscal Year Ending June 30, 1905. (Frank W. Shumway, Secy.) Lansing, Mich.: Pub. Doc. Cloth; 6¼ × 9¼ ins.; pp. 214.

BOARD OF HEALTH OF THE STATE OF NEW JERSEY.—Annual Report, 1906, and Annual Report of the Bureau of Vital Statistics. (Henry Mitchell, Secy. Board of Health.) Trenton, N. J.: Pub. Doc. Cloth; 5¾ × 9 ins.; pp. 456; diagrams.

BOARD OF PUBLIC ROADS OF THE STATE OF RHODE ISLAND.—Annual Report, January, 1907. (Frederick E. Perkins, Secy.) Providence, R. I.: Pub. Doc. Cloth; 5¾ × 9¼ ins.; pp. 38; numerous plates.

CHARLES RIVER BASIN COMMISSION.—Annual Report, Dec. 1, 1906. (Hiram A. Miller, Chief Engineer; William S. Youngman, Secy.) Boston, Mass.: Pub. Doc. (No. 71). Paper; 5¾ × 9¼ ins.; pp. 81; folding and other plates.

CHEMICAL REAGENTS.—Their Purity and Tests. A New and Improved Text Based on and Replacing the Latest Edition of Krauch's "Die Prüfung der Chemischen Reagentien auf Reinheit." By E. Merck. Authorized Translation by Henry Schenck, A. B. (Harvard). New York: D. Van Nostrand Co. Cloth; 6 × 9½ ins.; pp. 250. $1.50, net.

COMMISSIONER OF DAMS AND RESERVOIRS (Rhode Island).—Annual Report Made to His Excellency James H. Higgins, Governor, January, 1907. (Walter C. Simmons, Commissioner.) Providence, R. I.: Pub. Doc. Paper; 5¾ × 9 ins.; pp. 30; folding and other plates.

THE CONSTRUCTION OF DYNAMOS.—(Alternating and Direct-Current.) A Text-Book for Students, Engineer-Constructors, and Electricians-in-Charge. By Tyson Sewell, Assoc. M. Inst. E. E., Lecturer and Demonstrator in Electrical Engineering at the Polytechnic, Regent St., London; Author of "Elements of Electrical Engineering." New York: D. Van Nostrand Co. London, England: Crosby Lockwood & Son. Cloth; 5¼ × 8¼ ins.; pp. 316; 233 illustrations in the text. $3, net.

DETAILS OF MILL CONSTRUCTION.—By Hawley Winchester Morton, Architect. Boston, Mass.: Bates & Guild Co. Cloth; 9½ × 12½ ins.; 25 plates. $2.

ELECTRICITY IN MINING.—By Sydney F. Walker, M. Inst. E. E., M. Inst. Min. E., Assoc. M. Inst. C. E., etc. New York: D. Van Nostrand Co. Cloth; 5½ × 8¾ ins.; pp. 385; 31 plates and 163 text illustrations. $3.50, net.

ELEMENTS OF ELECTRIC TRACTION FOR MOTORMEN AND OTHERS.—By L. W. Gant, Lecturer in the Electrical Engineering Department of the Leeds Institute Technical School. New York: D. Van Nostrand Co. Cloth; 5½ × 8¾ ins.; pp. 217; 38 illustrations in the text. $2.50, net.

A HANDBOOK OF WIRELESS TELEGRAPHY.—Its Theory and Practice. For the Use of Electrical Engineers, Students and Operators. By James Erskine-Murray, D. Sc., M. Inst. E. E. New York: D. Van Nostrand Co. London, England: Crosby Lockwood & Son. Cloth; 5½ × 8¾ ins.; pp. 322; 131 illustrations, mostly in the text, and 11 tables. $3.50, net.

DIE HERSTELLUNG DER DAMPFKESSEL.—By M. Gerbel. Berlin, Germany: Julius Springer. Paper; 5½ × 8¼ ins.; pp. 82; 60 illustrations in the text. 2 marks; American price, 80 cts.

HIGHWAY COMMISSIONER (Connecticut).—Biennial Report to the Governor, for the Years Ended Dec. 31, 1905 and 1906. Including State Specifications and Public Laws Governing Town Management of Highways. (James H. Macdonald, Commissioner.) Hartford, Conn.: Pub. Doc. (No. 36). Cloth; 5¾ × 9 ins.; pp. 251 + 81; folding and other plates.

ILLINOIS SOCIETY OF ENGINEERS AND SURVEYORS.—Proceedings of the Society at the 22d Annual Meeting, Held at Peoria, Ill., Jan. 23, 24 and 25, 1907. (E. E. R. Tratman, Secy., 1636 Monadnock Block, Chicago, Ill.) Paper; 6 × 9 ins.; pp. 220; illustrated. 50 cts.

INDIANA ENGINEERING SOCIETY.—Proceedings of the 27th Annual Meeting, Held at Indianapolis, Jan. 17, 18, 19, 1907. Indianapolis, Ind.: The Society (Charles Carroll Brown, Secy., 408 Commercial Club Building). Paper; 6 × 9 ins.; pp. 212; illustrated.

INDUSTRIAL ALCOHOL.—The Production and Use of Alcohol for Industrial Purposes and for Use as an Illuminant and as a Source of Motive Power. By John Geddes M'Intosh, Author of "The Technology of Sugar," etc., Lecturer on Manufacture and Applications of Industrial Alcohol at the Polytechnic, Regent St., London. London, England: Scott, Greenwood & Son. New York: D. Van Nostrand Co. Cloth; 5¼ × 8¾ ins.; pp. 252; 78 illustrations in the text and 25 tables. $3, net.

THE INTERACTION OF DILUTE SOLUTION OF AMMONIUM SALTS AND VARIOUS FILTERING MEDIA.—By Gilbert John Fowler, D. Sc., F. I. C., and Percy Gaunt, Assoc. M. S. T. (Reprinted from the Journal of the Society of Chemical Industry, Manchester Section, July 15, 1907.) Paper; 4¾ × 7 ins.; pp. 24.

INTERNATIONAL ASSOCIATION OF FIRE ENGINEERS.—Proceedings of the 34th Annual Convention, Held at Dallas, Tex., Oct. 9-12, 1906. (James McFall, Secy., Roanoke, Va.) Paper; 5¾ × 9¼ ins.; pp. 204; illustrated.

INTERNATIONAL RAILWAY CONGRESS ASSOCIATION.—Bulletin (English Edition), Vol. XXI., No. 6, June, 1907. (M. Weissenbruch, Secy., 49, rue du Poincon, Brussels, Belgium.) London, England: P. S. King & Son. Paper; 7¼ × 9½ ins.; pp. 587 to 665; illustrated. $6 per year.

IRON AND STEEL INSTITUTE.—Journal, Vol. LXXIV. Edited by Bennett H. Brough, Secy. London, England: E. & F. N. Spon, Ltd. New York: Spon & Chamberlain. Cloth: 5½ × 8¾ ins.; pp. 247; 45 plates and numerous text illustrations.

IRRIGATION.—Its Principles and Practice as a Branch of Engineering. By Sir Hanbury Brown, K. C. M. G., M. Inst. C. E. London: Archibald Constable & Co. New York: D. Van Nostrand Co. Cloth; 5¾ × 9 ins.; pp. 301; plates and text illustrations. 16 shillings, net; American price, $5, net.

IRRIGATION BRANCH OF THE PUBLIC WORKS DEPARTMENT IN THE MADRAS PRESIDENCY.—Administration Report for the Year 1905-1906. Madras, India: Pub. Doc. Boards; 8 × 13 ins.; pp. 138; diagrams and folding map. 7s. 3d.; American price, $2.90.

LABORATORY WORK IN ELECTRICAL ENGINEERING.—(Preliminary Grade.) A Series of Laboratory Experiments for First and Second Year Students of Electrical Engineering. By John Roberts, Jr., Diplomate in Electrical Engineering, School of Technology, Manchester; Lecturer in Engineering, Municipal Technical School, Blackburn. New York: D. Van Nostrand Co. Cloth; 5½ × 8¾ ins.; pp. 218; 103 illustrations in the text and 14 tables. $2, net.

THE MARINE STEAM TURBINE.—A Practical Description of the Parsons Marine Turbine as Presently Constructed, Fitted and Run, Including a Description of the Denny & Johnson Patent Torsion Meter for Measuring the Transmitted Shaft Horse-Power, and Containing Fifty Questions (with Solutions) on Elementary Turbine Design. By J. W. Sothern, Author of "Verbal Notes and Sketches for Marine Engineers," etc. Second Edition. New York: D. Van Nostrand Co. London, England: Whittaker & Co. Cloth; 5½ × 8½ ins.; pp. 163; folding and other plates, and text illustrations. $2.50, net.

DAS MATERIAL UND DIE STATISCHE BERECHNUNG DER EISENBETONBAUTEN.—With Special Reference to Building Construction. By Max Foerster, Professor of Structural Engineering at the Dresden Technical College. [Fortschritte der Ingenieurwissenschaften, Second Series, Part 13.] Leipzig, Germany: Wilhelm Engelmann. Paper; 7½ × 11 ins.; pp. 248; 93 illustrations in the text. 6 marks; American price, $2.40.

THE MICHIGAN ENGINEER.—Containing the Proceedings of the Michigan Engineering Society for the Year 1907. Grand Rapids, Mich.: The Society (A. L. Holmes, Secy.). Paper; 6 × 8¾ ins.; pp. 242; folding plates and text illustrations.

MODERN SCIENCE CLUB OF GREATER NEW YORK.—Annual Year Book, 1907. (Brooklyn, N. Y.: The Club. J. A. Donnelly, Secy., 125 South Elliott St.) Paper; 6¾ × 10 ins.; pp. 96; illustrated.

"NATIONAL ELECTRICAL CODE."—1907. Rules and Requirements of the National Board of Fire Underwriters for the Installation of Electric Wiring and Apparatus, as Recommended by the Underwriters' National Electric Association. Paper; 3½ × 5¾ ins.; pp. 153.

NOTES ON THE DIFFERENTIATION OF *B. COLI* IN WATER.—Francis F. Longley and Warren U. C. Baton. (Reprinted from "The Journal of Infectious Diseases," Vol. 4, No. 3, June, 1907.) Paper; 6½ × 9½ ins.; pp. 397 to 416; six diagrams and seven tables.

ON THE ART OF CUTTING METALS.—By Mr. F. W. Taylor. An Address Made at the Opening of the Annual Meeting in New York, December, 1906. New York: The American Society of Mechanical Engineers. Cloth; 6 × 9¼ ins.; pp. 248; 24 folding plates. $3.

RAILROAD AND WAREHOUSE COMMISSION OF THE STATE OF ILLINOIS.—36th Annual Report. Railroads for the Year Ending June 30, 1906; Grain Inspection Department for the Year Ending Oct. 31, 1906; Office Expenses for the Year Ending Nov. 30, 1906. (William Kilpatrick, Secy.) Springfield, Ill.; Pub. Doc. Flexible leather; 5½ × 8½ ins.; pp. 623; folding tables.

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